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I S T C
М Н Т Ц

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Our Ref.: OPA-AN-028

31 July, 2003

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Subject: Sending Annual Project Reports to the Parties

Enclosed please find a copy of Annual Report of ISTC Project No. 2083.

Michael KRÖNING

Executive Director

Enclosures: Annual Report

AUG 05 2003

I S T C

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TRANSMISSION FORM
FOR ISTC PROJECT ANNUAL REPORT

(The First Phase of the Project)

#2083p

PROJECT TITLE: Development of technical infrastructure and program of pilot testing of flow lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator

EXECUTIVE DIRECTOR STATEMENT:

Please find enclosed a copy of the Annual Report (the 1st Phase – 1 year 5 months) of Project # 2083p, including the Summary Report, the main text of the Annual Report, presented by project participants, and an Evaluation of the Annual Project Report, prepared by the ISTC Secretariat.

CONFIDENTIAL INFORMATION:

1. Budget items of the Annual Project Report.
2. Technical information, included in the main text of the Annual Project Report.

OTHER COMMENTS:

for Michael Kröning, Executive Director

11 July 03

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EVALUATION FORM FOR ISTC PROJECTS ANNUAL REPORTS

The First Phase of the Project

Project Attributes	
Project Number	# 2083-P
Project Title	Development of technical infrastructure and program of pilot testing of flow lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator
Leading Institute	SSC RF IPPE named after Academician A.I.Leypunsky, Obninsk, Kaluga reg., Russia
Project Manager	Evgeny I. Yefimov
O.C.D.	01.10.2001
Duration	12 months, extended by 5 months
Total Budget	$100 000 (Partner)
Funding Parties	Los-Alamos National Laboratory, Los-Alamos, NM, USA
ISTC Project Manager	**L.V. Tocheny**
ISTC Deputy Executive Director	**M. Okubo**

Major Technical Progress for the first year

I. The project is proceeding in accordance with the Work Plan schedule.

The #2083 project activity related to development of new pilot flow-type lead-bismuth target of 1 MW power and its testing in the U.S. Los Alamos National Laboratory LANSCE accelerator.

The first phase of the program (design, fabrication and primary non-radiation testing) has been developed in the frames of #559 project, 1998 – 2000.

The second phase (in the frames of #2083 project) includes:

- Target shipment to LANL;
- Preliminary design of the proper service systems in LANL, needed for isothermal beam-off tests of the target.

After the project has started the US side decided to deliver the target to University of Nevada, Las Vegas (UNLV) with plans to use it as the lead-bismuth stand without irradiation.
Therefore It was agreed to prolong the project duration for 5 months without additional funding for target adapting to new conditions.
All 15 sub-tasks of the Work Plan, including transport, unpacking and inspection of the target and target complex in UNLV, were fulfilled completely.
The report (39 pages) contents description and schemes of the target complex, target systems (heat-exchanger, coolant technology, gas-vacuum, etc.), and packing for shipment.

The Work Plan was fulfilled completely.

II. Published Papers, Presentations, Trips(Conferences, Meetings).

The IPPE delegation (2 – 3 persons, including Project Manager) visited USA two times: for working meeting in Las Vegas (August 2002) with post-shipping inspection, and for participation in the international conference ADTTA'01 in Reno, Nevada (November 2001) with 5 presentations.

III. Collaboration between CIS Institutes.
The IPPE is realizing the project alone.
IV. Partnership with Foreign Institutes.
Close partnership was achieved IPPE with LANL and UNLV, USA. Two visits of the IPPE team to USA took place. There is principal agreement on project prolongation with additional funding with UNLV as the new partner.
Financial Information.
Actual expenditure totals for 6 quarters is \$95 000.37 The expenditure on grants amounts to \$75 734.0 (as it was estimated).
Equipment and Materials.
No equipment was purchased. Total cost of materials: \$109.5
Results of On-site Project Monitoring
The ISTC SPM visited the IPPE with on-site monitoring (Nov 2001 and Nov 2002). All remarks are taken into account. PM keep a close contact with the ISTC.
Comments.
1. There are principal changes: the target site (UNLV university instead of LA National Laboratory), and the science program (deletion of radiation on-beam tests with accelerator). 2. There is IPPE-UNLV agreement on project prolongation with additional funding with UNLV as the new partner.

Senior Project Manager
Date: 9.07.03

Deputy Executive Director
Date: 10. July 03

I S T C

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International Science and Technology Center

ISTC 2083p

Final technical report on the first phase of ISTS Project #2083p

Development of technical infrastructure and programs of testing pilot molten lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator

(01.10.1998 – 28.02.2003)

Summary for unlimited distribution

Project Manager Doctor of Engineering
Evgueni Yefimov

State Scientific Center of Russian Federation –
Institute of Physics and Power Engineering named after A.I. Leypunsky

Obninsk
2003

Introduction

In 1998-2001 in the frames of ISTS Project #559 SSC RF IPPE and EDO "Gidropress" designed, fabricated and tested (without proton beam) a pilot molten lead-bismuth target for proton beam of 1 MW power. The target (the target complex TC-1) was developed for the conditions (infrastructure) of LANSCE accelerator in Los-Alamos National Laboratory (LANL). Proton energy Ep=800 MeV, proton current Ip ~1 mA. TC-1 tests in beam-on condition have been planned.

In 2001 ISTC partner Project #2083p was launched by title "Development of technical infrastructure and programs of testing pilot molten lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator".

The Project duration was 1 yeas from 01.10.2001 to 30.09.2002.

The Project had two main tasks:
- TC-1 transportation to LANL;
- Preliminary design of the external system in LANL needed for isothermal tests of TC-1 in LANL without proton beam.

Because of shortage of funding for the tests of TC-1 in LANL planned earlier the target was delivered to University of Nevada, Las Vegas (UNLV) with the plans to use it as lead-bismuth facility without irradiation.

In this connection amendments were made in the original Work Plan and the Project was prolonged for 5 month (up to 28.02.2003) in the frames of the initial funding (the 1-st phase of the Project).

Recently Addendum to the Work Plan of the Project 2083 has been developed and the Project was prolonged for 24 months with additional funding from UNLV as second Partner (2-nd phase of the Project). The main task of second phase is to start up TC-1 in UNLV and to carry out resource isothermal tests.

In this report the main results of the activity are presented on the first phase of the Project #2083p for period from 01.10.2001 to 28.02.2003.

1.Brief information about the Project # 2083p

1.1. Project Title

Full Title: <u>**Development of technical infrastructure and programs of testing pilot molten lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator**</u>

1.2. Project Manager

Name: Evgeny I. Yefimov			
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Region: Kaluga reg.		**Country:** Russia	**Zip Code:** 249020
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Government Agency: Ministry of Russian Federation for Atomic Energy			

1.3. Participating Institutions

Leading Institution

Name: SSC RF IPPE named after Academician A.I.Leypunsky			
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Region: Kaluga reg.		**Country:** Russia	**Zip Code:** 249020
Name of Signature Authority: Viktor V. Kuzin			
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1.4. Partner

Name: Los Alamos National Laboratory			
Address:	**Street:** P. O. Box 1663 MS H854		**City:** Los-Alamos
Region/State: NM		**Country:** USA	**Zip Code:** 87545
Name of Signature Authority: James Jefferis			
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Name of Contact Person: Keith Woloshun			
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The duration of the 1-st phase is 17 months from 01.10.2001 to 28.02.2003.

The duration of the Project as a whole with UNLV implementation as a Partner 41 months from 01.10.2001 to 28.02.2005.

2. Brief characteristic of the Project Work Plan

Initially the Project tasks were formulated as following.

Task 1. Engineering preparation and packing the TC-1 for transportation.

1.1. Dismantling TC-1 from the test facility and TC-1 conservation.

1.2. Package development and TC-1 packing.

1.2.1. Consideration of requirements of Russian Ministries for Road Communication and Merchant Marine for target shipment.

1.2.2. Analysis of the target complex and package stresses due to possible vibrations and drops.

1.2.3. Design of package container.

1.2.4. Fabrication of package container.

1.2.5. TC-1 packing.

1.3. Dismantling and packing data acquisition and control (DAC) system.

1.4. Issue of packing documentation

Task 2. Preparation and coordination of the documents on TC-1 exportation with RF regulation authorities.

2.1 Preparation and obtaining documents from control services of SSC RF IPPE.

2.1.1. Preparation and obtaining appraisal from special commission of SSC RF IPPE.

2.1.2. Preparation and obtaining appraisal from export control service of SSC RF IPPE.

2.2 Preparation and obtaining appraisal from Export Counsel of Minatom.

2.2.1. Preparation of substantiation for Agreement on TC-1 delivery to LANL.

2.2.2. Preparation of explanatory report for Agreement.

2.2.3. Documents coordination with Minatom departments.

2.2.4. Appraisal obtaining from Export Counsel of Minatom.

2.3 Preparation of necessary documents and license obtaining (or permission) for TC-1 exportation in Export Control department of Ministry of Economic Development RF.

2.4 Preparation of necessary documents for Custom procedures.

Task 3. Physical shipment of target complex and data acquisition and control (DAC) system from Russia to U.S.

Task 4. Unpacking and inspection at LANL of the target complex and DAC system.

4.1. Unpacking and inspection of TC-1 conditions (including coolant circuit and gas system) and DAC system and analysis of its readiness for beam-off tests at LANL.

4.2. Issue of inspection protocol.

Task 5. Development of testing and investigation programs for TC-1 in LANL.

5.1. Development of TC-1 testing program in beam-off condition and specification parameters measured.

5.2. Development of testing and experimental investigations programs on TC-1 in beam-on condition and specification thermal, technology and radiation parameters measured.

5.3. Issue of testing programs.

Task 6. Development and design of external systems for TC-1 testing in beam-off condition.

6.1. Basic design of heat exchanger cooling system.

6.2. Basic design of non-active gas system.

6.3. Basic design of steel container for TC-1.

6.4. Modernization of DAC system for TC-1 testing in beam-off conditions.

6.5. Preparation and issue of Project final report.

The Project duration of these tasks fulfillment was planned 12 month from 01.10.2001 to 30.09.2002. Because of TC-1 transportation to UNLV the tasks 4-6 were changed as following.

Task 4. Unpacking and inspection of the TC-1 at UNLV, Las Vegas, NV.

Task 5. Preliminary development of the TC-1 start-up and test programs for conditions of the UNLV.

Task 6. Development of conceptual design of external systems of the TC-1 for its start-up and testing at UNLV.
Task 6.1. Preliminary development of the conceptual design of the TC-1 heat exchanger cooling system under isothermal regime of the TC-1 operation with circuit heating due to electric supply and EM-pump operation.
Task 6.2. Development of the conceptual design of gas-vacuum system
Task 6.3. Development of the conceptual design of coolant technology system
Task 6.4. Preparation and issue of the Project 2083 completion papers, including final Project report, approval them at Minatom and submitting to the ISTC and Partner.

In order to carry out the tasks changed the Project was prolong ed for 5 month up to 28.02.2003.

This report comprises the main results of the activity on the Project #2083 for the period from 01.10.2001 to 28.02.2003, which is considered as the 1-st stage of the Project.

The following tasks were formulated for the 2-nd phase of the Project.

Task 7. Design and fabrication of the external system for TC-1 operation in UNLV.
7.1. The system of electric supply for MHD-pump and electric heating up.
7.2. The gas – vacuum system.
7.3. The system for heat exchanger cooling.
7.4. Modernization of monitoring, control and scram protection system (MC SPS).
Task 8. TC-1 installation and its connection with the external systems.

Task 9. Adjusting and tuning MCSPS in cold conditions without TC heating up.

Task 10. Development of the guides for TC-1 operation in UNLV.

Task 11. TC-1 heating up, its start-up without water feeding the system of the heat exchanger cooling, selective repeating of TC-1 thermal and engineering tests in IPPE.
11.1. Adjusting the system of electric supply.
11.2. Testing the system of electric heating.
11.3. Heating up and filling the circulation loop from the drainage tank.
11.4. Measurements of volt-ampere and other characteristics of MHD-pump.
11.5. The coolant draining to the drainage tank and TC-1 cooling.

Task 12. Commissioning the system of the heat exchanger cooling.

Task 13. TC-1 resource testing for 3.000 hours in isothermal conditions.
13.1. Analysis of the test results.

Task 14. Development of comprehensive scientific program of further investigation and TC-1 modification.

Task 15. The results systematization and the final report preparation.

Technical approach and methodology can be formulated as following: summarizing and adaptation of the results on development and fabrication in Russia of the pilot molten lead-bismuth target of 1 MW power obtained in the frames of ISTC Project 559 earlier accomplished. Russian and USA law and regulation documents are used for management and realization of TC-1 exportation to LANL. The results of TC-1 thermal and engineering tests in SSC RF IPPE are used for development of external systems ,exploitation guides,TC-1 start-up and tests in UNLV.

3.Brief description of TC-1 design

The target complex TC-1 is a circulation lead-bismuth loop.

TC-1 components (target itself generating neutrons, MHD-pump, volume compensator (VC), heat exchanger (HE), drainage tank (DT), siphon interruption device (SIP), pipelines, sensors and cables of Monitoring control and scram protection system (MCSPS)) are arranged inside supporting rectangular metal frame with dimensions 640x710x4075 mm.

Specific feature of TC-1 design is the fact that because of small distance between the beam axis and the floor (~400 mm) in LANL DT is placed above the target and operations of coolant drainage from loop into DT and vise versa are realized by means of formation necessary gas (argon) pressure over free coolant surface in DT and VC. This complicates technology of TC-1 exploitation.

The primary circuit is destined for providing the coolant circulation through the target and removal of the heat released in the target into the heat exchanger cooling system. The primary circuit comprises the circulation loop and the drainage tank, which are connected with each other by pipelines for filling (draining) through siphon interruption device.

The primary circuit components are as following:
target itself, MHD-pump, heat-exchanger, volume compensator, drainage tank, siphon interruption device, pipelines.

TC-1 cover gas system is designed to maintain inert atmosphere above free surface of the coolant, to provide filing and draining regimes as well as regimes of the coolant quality maintenance on the phase of pilot tests in IPPE.

The heat exchanger cooling system is design to receive heat from the coolant of the circulation loop and transfer it to the external cooling system outside the sealed container.

The radiation shielding cooling system is designed to receive heat released in the shielding and transfer it to the external cooling system outside the sealed container.

4. TC-1 conservation and packing

The disconnection of target circuit TC-1 from test facility system and its conservation have been made in accordance with guidance including:
-the pipe for coolant transmission into the TC-1 was cut and welded;
-the inner gas cavities were filled with argon by pressure up to 0.5 mPa. The shut-off valves were closed and sealed with thread plugs with gaskets;
-the inner cavities of cooling pipelines were blown with argon and sealed with thread plugs with gaskets;
-response elements (plugs) were put at the electric connectors of supply cables and covered by protection tape.

-the input/output pins of thermal couples were reeled into hanks and fixed on upper plate of TC-1.
-TC-1 window was closed with transport protection cover.

Package was designed and fabricated. The target complex TC-1 is packed into the metallic container

Elements and blocks of data acquisition and control system were packed in separate packages (wooden boxes). These elements and blocks were delivered by LANL to SSC RF IPPE for thermal and engineering tests of TC-1 on conditions of subsequent return.

To indicate stroke loads during transportation two accelerometers of NON-RESETABLE IMPACT INDICATOR type with response threshold of 5g were installed on TC-1 in perpendicular planes.(see Fig.1 of Addendum).

The calculation was made for strength of the most loaded elements of the package.

Stress arising in the most loaded elements under lifting with jerk and transportation do not exceed permissible values.

5. Preparation and coordination of the documents on TC-1 transportation with regulation authorities of Russian Federation

Important work was carried out on preparation and coordination of the documents with regulation authorities of Russian Federation needed for TC-1 delivery to USA in accordance with p.2 of the Work Plan "Preparation and coordination of the documents on TC-1 exportation with RF regulation authorities"

As a result of this expertise accomplished in accordance with RF legislation on the procedure provided for Minatom enterprises Minatom Export Counsel decision was issued that export item (the target complex TC-1) does not fall under export control.

After obtaining Export Counsel decision necessary papers were prepared and permission for TC-1 exportation without license was obtained in Department of Export Control in Ministry of Economic Development.

Further the following works were carried out.
1. Choice of transport agent for TC-1 transportation to USA. In accordance with American party tender was announced among transportation companies. Choice was made by LANL represantivies in favor of Russian branch of American Company "GeoLogistics".

2. The scheme describing functional ties of TC-1 components was prepared.

3. Final version of package lists in Russian and in English was validated.

4. Final marking 4 boxes with TC-1 and with elements and block of data acquisition and control system with accordance of RF state standards and international rules of goods transportation.

5. Drawing up a statement of TC-1 readiness for consignment to USA.

6. Co-ordination with ISTC and transport agent "GeoLogistics" joint efforts, itinerary, time-table of TC-1 movement from Obninsk.

7. Preparation of the final version of conditions and features of TC-1 delivery to USA. Shipment was realized under EXW conditions as described in the INCOTERMS-90.

8. Loading TC-1 and its delivery to Moscow on Butovo custom together with "GeoLogistics" representative.

9. Custom validation together with ISTC representatives.

10. Consignment to Saint -Petersburg for further transportation to USA.

6. Inspection of TC-1 conditions after transportation

In the course of transportation in principle some damage of TC-1 is possible and inspection (incoming control) of TC-1 conditions was planned after delivery to USA. The guide for incoming control was developed. It is presented as Addendum to this report.

Incoming control purpose is to check serviceability of TC-1 after transportation.

The incoming control includes the following stages:
- external visual inspection;
- checking accelerometers indicating shock loads applied at the target complex TC-1 during its transportation;
- checking condition of preservation of the inner surfaces;
- inspection of electric heaters, control systems and measurement of MHD pump insulation resistance.

Incoming control was carried out in UNLV early in August 2002 according to p.A-C with participation SSC RF IPPE representatives. Checking according to p.D should be made later before TC-1 connection with the external systems.

Visual inspection showed that there was no any visual traces of TC-1 damage.

Both accelerometer snapped, this was evidence that during transportation stroke loads had place with acceleration more than 5g.

Excessive argon pressure in the inner cavity of TC-1 was measured as ~0.1 MPa (13 psi).This is evidence that TC-1 loop is seal ed, there was no air penetration, and the inner surfaces are in regular conditions without oxidation.

7. Conceptual design of TC-1 external systems for the conditions of University of Nevada

Development of a number of external systems that are needed for the target complex TC-1 commissioning in University of Nevada (UNLV) has been carried out on conceptual level.

These systems comprise:
1. Heat exchanger cooling system.
2. Coolant technology system.
3. Gas-vacuum system.

This development includes basic schemes with description of component characteristics and parameters. External systems construction will be made, apparently, using components and equipment produced in USA. Detail engineering design of these systems can be performed together with USA specialists.

Heat exchanger cooling system designed for heat removal released in the circulation loop through the heat exchanger (HX).

Specific feature of lead-bismuth coolant is the fact that under interaction with oxygen slags (phases containing oxides of the coolant itself, components of structural steels and others)can be formed. The slags can deposit on the loop surfaces, decrease transport cross-sections of channels (up to its blocking), aggravate thermal and hydraulic performance of the loop.

Therefore for successful operation of the loop it is necessary:
- to restrict contacts of the coolant and the loop with media containing oxygen, in particular, with air;
- to clean the coolant and the loop of excessive oxygen (in the event of this contact appearance).

These tasks are solved under coolant technology realization. "Coolant technology" means a complex of management and engineering measures as well as processes and systems (devices) for their realization. These measures are applied for providing given (required) conditions of the coolant and the loop surfaces under construction, commissioning, operation and repair works on TC-1.

Coolant technology system is a set of devices for coolant technology procedures realization.

Gas vacuum system is designated for realization necessary pressure of inert gas and vacuum in TC-1 and the facility cavities as well as for preparation of gaseous mixtures and providing its injection into TC-1 loop using components of the coolant technology system.

8. The program of TC-1 start-up and testing in UNLV

This program has been presented in the Work Plan of second phase of the Project (the tasks 7-15, seen part 2).

The tasks 7, 8 are development, fabrication of the external system and TC-1 connection with these systems. Before this connection serviceability conductivity of electric heating system and thermocouple transducers, electric insulation resistance of MHD-pump, electric heaters and transducer as well (p.D of the guide, see Addendum).
Some modernization of data acquisition and control system will be required (p.7.4) in comparison with the system that had been realized on thermal and engineering tests of TC-1 in SSC RF IPPE, in particular, because of appearance of the heat exchanger cooling system that the control is needed for.

Development of exploitation guides is necessary for UNLV condition, one guide for TC-1 tests without heat exchanger cooling system on other for resource testing (the task 13).

At present the procedures of the coolant technology during TC-1 start up and testing in UNLV are not planned taking into account the fact that the circulation loop of TC-1 is in inert atmosphere and sealed (there is no argon leaks).

The proposals on TC-1 reconstructions and the program of further investigation shall be developed with consideration of the experience gained in TC-1 isothermal tests. It is assumed that later some laboratory on investigation of thermal hydraulic, corrosion in lead-bismuth coolant will be realized in UNLV on TC-1 basis.

Conclusion

As the main results obtained in the first phase of the Project #2083 one can note the following.

1. Package for the target complex TC-1 transportation to USA was designed and fabricated.

2. TC-1 was disconnected from test facility, conservated and packed. Relevant package was fabricated and elements and blocs of data acquisition and control system were packed. These blocks and elements have been delivered by LANL earlier for thermal and engineering tests of TC-1 in SSC RF IPPE on the conditions of their return.

3. The documents on TC-1 exportation to USA were prepared and coordinated with regulation authorities of Russian Federation. Decision of Minatom Export Consel that export item (TC-1) does not fall under export control and Permission of Department of Export Control in Ministry of Economic Development for TC-1 exportation without license were obtained.

4. Together with ISTC custom validation of export items was made and transport agent choosed. (Russian branch of "GeoLogistics" Company) TC-1 was delivered in June 2002 to University of Nevada State (UNLV).

5. The guide was developed for inspection (incoming control) of TC-1 conditions after its transportation to USA. Early in August incoming control was carried out in UNLV after TC-1 delivery. The control confirmed TC-1 serviceability.

6. Conceptual design was carried out for the external systems needed for TC-1 start in heat exchanger cooling, gas-vacuum system and the coolant technology system.

7. The program of TC-1 start-up and isothermal testing in UNLV was developed. This program is the basis of the Work Plan of the second phase of the Project #2083. Period of the Project validity was prolonged for 2 years with UNLV funding as a Partner.

Ministry of the Russian Federation for Atomic Energy
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" APPROVED"
Deputy Director General

V.Chitaykin
"22" 2002

Development of technical infrastructure and programs of testing pilot molten lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator

(Technical report on the first phase of ISTC Project #2083p, 01.10.2001 – 28.02.2003)

Project #2083p Manager E. Yefimov

Obninsk
2003

Contents

Introduction

In 1998-2001 in the frames of ISTS Project #559 SSC RF IPPE and EDO "Gidropress" designed, fabricated and tested (without proton beam) a pilot molten lead-bismuth target for proton beam of 1 MW power. The target (the target complex TC-1) was developed for the conditions (infrastructure) of LANSCE accelerator in Los-Alamos National Laboratory (LANL). Proton energy Ep=800 MeV, proton current Ip ~1 mA. TC-1 tests in beam-on condition have been planned.

In 2001 ISTC partner Project #2083p was launched by title "Development of technical infrastructure and programs of testing pilot molten lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator".

The Project duration was 1 yeas from 01.10.2001 to 30.09.2002.

The Project had two main tasks:
- TC-1 transportation to LANL;
- Preliminary design of the external system in LANL needed for isothermal tests of TC-1 in LANL without proton beam.

However DOE has not allocated funding for the tests of TC-1 in LANL planned earlier and the target was delivered to University of Nevada, Las Vegas (UNLV) with the plans to use it as lead-bismuth facility without irradiation.

In this connection amendments were made in the original Work Plan and the Project was prolonged for 5 month (up to 28.02.2003) in the frames of the initial funding (the 1-st phase of the Project).

Recently Addendum to the Work Plan of the Project 2083 has been developed and the Project was prolonged for 24 months with additional funding from UNLV as second Partner (2-nd phase of the Project). The main task of second phase is to start up TC-1 in UNLV and to carry out resource isothermal tests.

In this report the main results of the activity are presented on the first phase of the Project #2083p for period from 01.10.2001 to 28.02.2003.

1.Brief information about the Project # 2083p

1.1. Project Title

Full Title: <u>**Development of technical infrastructure and programs of testing pilot molten lead-bismuth target of 1-MW power using the U.S. Los Alamos National Laboratory LANSCE accelerator**</u>

1.2. Project Manager

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Government Agency: Ministry of Russian Federation for Atomic Energy		

1.3. Participating Institutions

Leading Institution

Name: SSC RF IPPE named after Academician A.I.Leypunsky		
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Region: Kaluga reg.	**Country:** Russia	**Zip Code:** 249020
Name of Signature Authority: Viktor V. Kuzin		
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1.4. Partner

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Tel: 505-667-8893	**Fax:** 505-665-2897	**E-mail**: jrjefferis@lanl.gov
Name of Contact Person: Keith Woloshun		
Tel: 505-665-6822	**Fax:** 505 6656927	**E-mail:** woloshun@lanl.gov

The duration of the 1-st phase is 17 months from 01.10.2001 to 28.02.2003.

The duration of the Project as a whole with UNLV implementation as a Partner 41 months from 01.10.2001 to 28.02.2005.

2. Brief characteristic of the Project Work Plan

Initially the Project tasks were formulated as following.

Task 1. Engineering preparation and packing the TC-1 for transportation.

1.1. Dismantling TC-1 from the test facility and TC-1 conservation.

1.2.1. Consideration of requirements of Russian Ministries for Road Communication and Merchant Marine for target shipment.

1.2.2. Analysis of the target complex and package stresses due to possible vibrations and drops.

1.2.3. Design of package container.

1.2.4. Fabrication of package container.

1.2.5. TC-1 packing.

1.3. Dismantling and packing data acquisition and control (DAC) system.

1.4. Issue of packing documentation

Task 2. Preparation and coordination of the documents on TC-1 exportation with RF regulation authorities.

2.1 Preparation and obtaining documents from control services of SSC RF IPPE.

2.1.1. Preparation and obtaining appraisal from special commission of SSC RF IPPE.

2.1.2. Preparation and obtaining appraisal from export control service of SSC RF IPPE.

2.2 Preparation and obtaining appraisal from Export Counsel of Minatom.

2.2.1. Preparation of substantiation for Agreement on TC-1 delivery to LANL.

2.2.2. Preparation of explanatory report for Agreement.

2.2.3. Documents coordination with Minatom departments.

2.2.4. Appraisal obtaining from Export Counsel of Minatom.

2.3 Preparation of necessary documents and license obtaining (or permission) for TC-1 exportation in Export Control department of Ministry of Economic Development RF.

2.4 Preparation of necessary documents for Custom procedures.

Task 3. Physical shipment of target complex and data acquisition and control (DAC) system from Russia to U.S.

Task 4. Unpacking and inspection at LANL of the target complex and DAC system.

4.1. Unpacking and inspection of TC-1 conditions (including coolant circuit and gas system) and DAC system and analysis of its readiness for beam-off tests at LANL.

4.2. Issue of inspection protocol.

Task 5. Development of testing and investigation programs for TC-1 in LANL.

5.1. Development of TC-1 testing program in beam-off condition and specification parameters measured.

5.2. Development of testing and experimental investigations programs on TC-1 in beam-on condition and specification thermal, technology and radiation parameters measured.

5.3. Issue of testing programs.

Task 6. Development and design of external systems for TC-1 testing in beam-off condition.

6.1. Basic design of heat exchanger cooling system.

6.2. Basic design of non-active gas system.

6.3. Basic design of steel container for TC-1.

6.4. Modernization of DAC system for TC-1 testing in beam-off conditions.

6.5. Preparation and issue of Project final report.

The Project duration of these tasks fulfillment was planned 12 month from 01.10.2001 to 30.09.2002. Because of TC-1 transportation to UNLV the tasks 4-6 were changed as following.

Task 4. Unpacking and inspection of the TC-1 at UNLV, Las Vegas, NV.

Task 5. Preliminary development of the TC-1 start-up and test programs for conditions of the UNLV.

Task 6. Development of conceptual design of external systems of the TC-1 for its start-up and testing at UNLV.
Task 6.1. Preliminary development of the conceptual design of the TC-1 heat exchanger cooling system under isothermal regime of the TC-1 operation with circuit heating due to electric supply and EM-pump operation.
Task 6.2. Development of the conceptual design of gas-vacuum system
Task 6.3. Development of the conceptual design of coolant technology system
Task 6.4. Preparation and issue of the Project 2083 completion papers, including final Project report, approval them at Minatom and submitting to the ISTC and Partner.

In order to carry out the tasks changed the Project was prolong ed for 5 month up to 28.02.2003.

This report comprises the main results of the activity on the Project #2083 for the period from 01.10.2001 to 28.02.2003, which is considered as the 1-st stage of the Project.

The following tasks were formulated for the 2-nd phase of the Project.

Task 7. Design and fabrication of the external system for TC-1 operation in UNLV.
7.1. The system of electric supply for MHD-pump and electric heating up.
7.2. The gas – vacuum system.
7.3. The system for heat exchanger cooling.
7.4. Modernization of monitoring, control and scram protection system (MC SPS).
Task 8. TC-1 installation and its connection with the external systems.

Task 9. Adjusting and tuning MCSPS in cold conditions without TC heating up.

Task 10. Development of the guides for TC-1 operation in UNLV.

Task 11. TC-1 heating up, its start-up without water feeding the system of the heat exchanger cooling, selective repeating of TC-1 thermal and engineering tests in IPPE.
11.1. Adjusting the system of electric supply.
11.2. Testing the system of electric heating.
11.3. Heating up and filling the circulation loop from the drainage tank.
11.4. Measurements of volt-ampere and other characteristics of MHD-pump.
11.5. The coolant draining to the drainage tank and TC-1 cooling.

Task 12. Commissioning the system of the heat exchanger cooling.

Task 13. TC-1 resource testing for 3.000 hours in isothermal conditions.
13.1. Analysis of the test results.

Task 14. Development of comprehensive scientific program of further investigation and TC-1 modification.

Task 15. The results systematization and the final report preparation.

Technical approach and methodology can be formulated as following: summarizing and adaptation of the results on development and fabrication in Russia of the pilot molten lead-bismuth target of 1 MW power obtained in the frames of ISTC Project 559 earlier accomplished. Russian and USA law and regulation documents are used for management and realization of TC-1 exportation to LANL. The results of TC-1 thermal and engineering tests in SSC RF IPPE are used for development of external systems ,exploitation guides,TC-1 start-up and tests in UNLV.

3.Brief description of TC-1 design

The target complex TC-1 is a circulation lead-bismuth loop. TC-1 component arrangement is presented in Fig.1.1 and 1.2.

TC-1 components (target itself generating neutrons, MHD-pump, volume compensator (VC), heat exchanger (HE), drainage tank (DT), siphon interruption device (SIP), pipelines, sensors and cables of Monitoring control and scram protection system (MCSPS)) are arranged inside supporting rectangular metal frame with dimensions 640x710x4075 mm.

Specific feature of TC-1 design is the fact that because of small distance between the beam axis and the floor (~400 mm) in LANL DT is placed above the target and operations of coolant drainage from loop into DT and vise versa are realized by means of formation necessary gas (argon) pressure over free coolant surface in DT and VC. This complicates technology of TC-1 exploitation.

The basic hydraulic scheme of TC-1 is presented in Fig.1.4. The components and pipelines of the following systems are shown in the scheme: the primary circuit, the cover gas system of the primary circuit, heat exchanger cooling system, internal (inside the container) shielding cooling system. The plans of the sensor location are also shown for monitoring, control and scram protection system.

The primary circuit is destined for providing the coolant circulation through the target and removal of the heat released in the target into the heat exchanger cooling system. The primary circuit comprises the circulation loop and the drainage tank, which are connected with each other by pipelines for filling (draining) through siphon interruption device.

The primary circuit components are as following:
target itself, MHD-pump, heat-exchanger, volume compensator, drainage tank, siphon interruption device, pipelines.

Forced circulation of the coolant through the circulation loop is provided by MHD-pump with head 0.102 MPa and capacity 14.2 m^3/h. The coolant is pumped through the target, then the coolant with temperature 320°C comes from beneath into intertubular space of the heat exchanger giving heat to water through walls of tube bunch and then it returns to the pump suck. The volume compensator is installed on the pump suck pipeline. By-pass flow of the coolant into the volume compensator from the upper part of the heat exchanger is realized through the pipeline with dimensions 14x2.

The system for the coolant filling (draining) comprises the pipeline 20x2 and it realizes the coolant pressurizing from the drainage tank into the circulation loop and vise versa. The tube 20x2 for primary filling is going from the drainage tank through the TC-1 lid. In delivery conditions this tube is welded.

TC-1 cover gas system is designed to maintain inert atmosphere above free surface of the coolant, to provide filing and draining regimes as well as regimes of the coolant quality maintenance on the phase of pilot tests in IPPE. The connection of the TC-1 cover gas system with the external gas system is realized:

- from gas cavity of the volume compensator through the pipeline 14x2 to maintain inert atmosphere above the coolant free surface in the volume compensator and to provide filling (draining) the circulation loop;
- from gas cavity of the drainage tank through the pipeline 14x2 to maintain inert atmosphere above the coolant free surface in the drainage tank to provide filling (draining) the circulation loop;
- from the siphon interruption device through the pipe line 14x2 to provide siphon interruption;
- from the pump suck pipeline through internal cavity of the volume compensator by means of the pipeline 14x2 for realization, if necessary, of technology operation for the coolant quality maintenance.

The heat exchanger cooling system is design to receive heat from the coolant of the circulation loop and transfer it to the external cooling system outside the sealed container. The system comprises the heat exchanger with a tube bunch of U-form type and 2 pipelines 45x3 for connection with the external cooling system.

The radiation shielding cooling system is designed to receive heat released in the shielding and transfer it to the external cooling system outside the sealed container. Six coils from tubes 14x2 are located in the radiation shielding. These coils are united in two parallel loops, each containing 3 coils. Coils are connected with external system through two pipelines 20x2.

In Fig.1.3 the scheme of union pipes for water and gas feeding and penetrations of cables for MHD-pump and thermocouple transducers is given on the upper lid of TC-1.

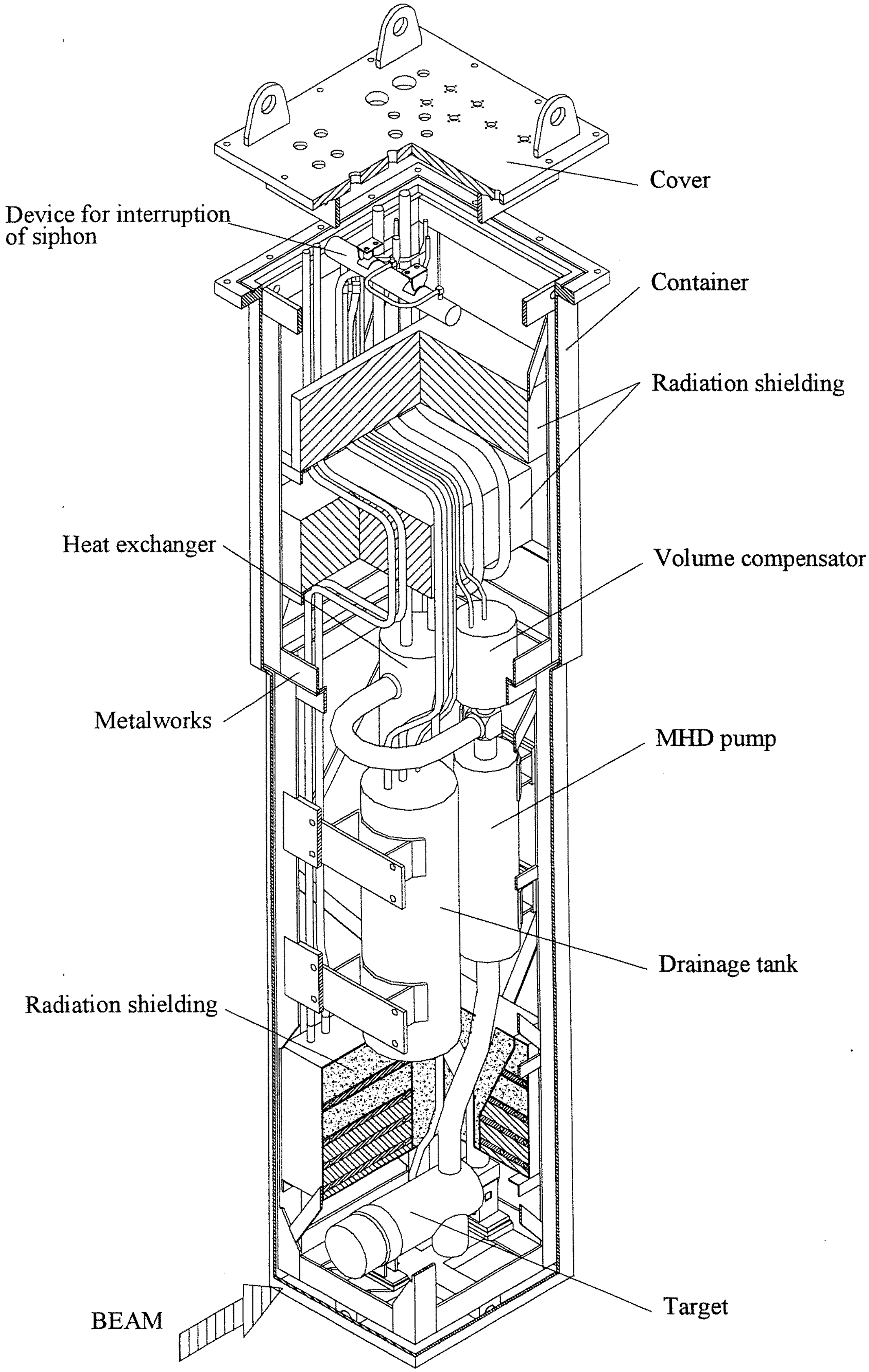
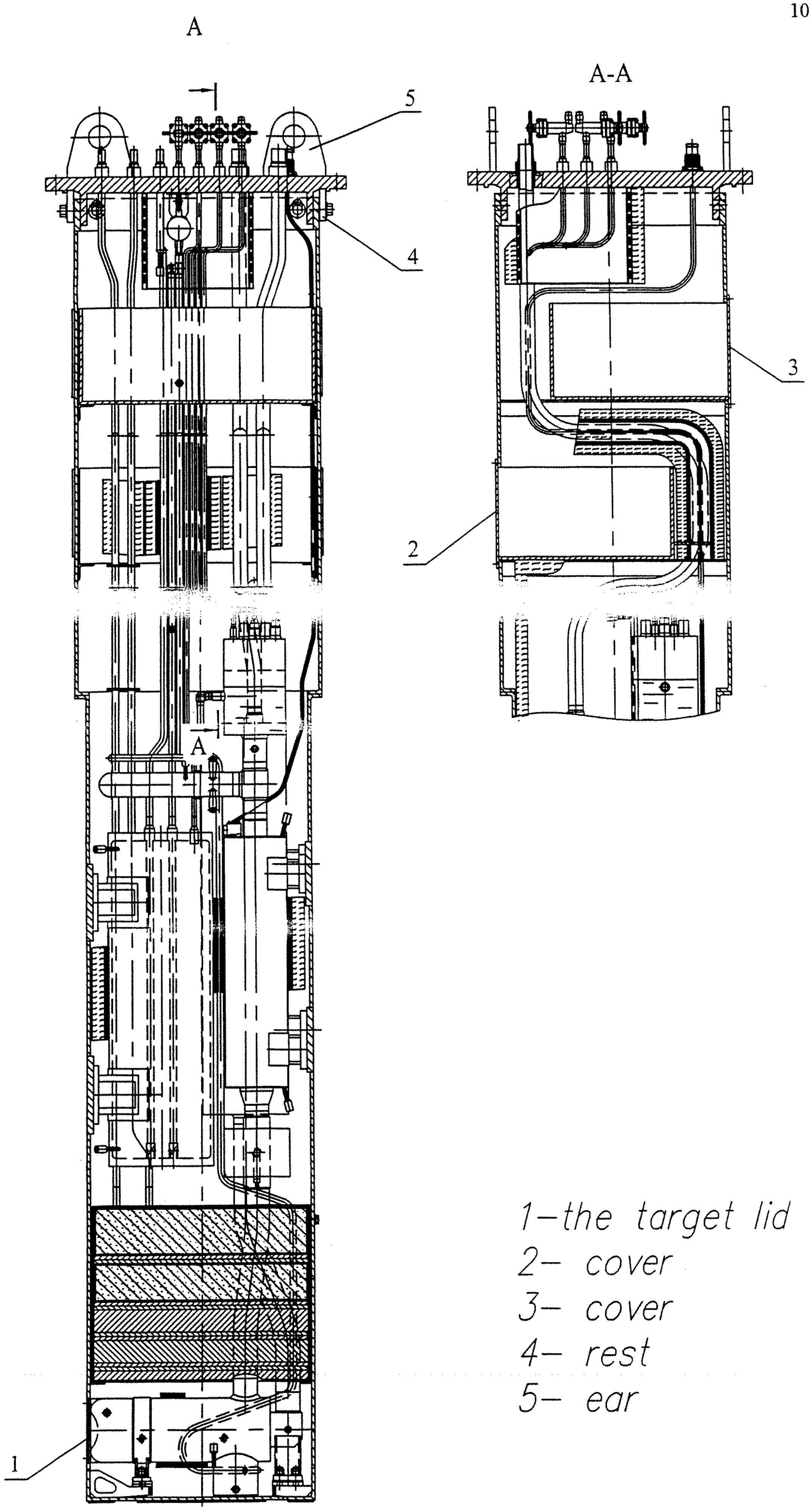
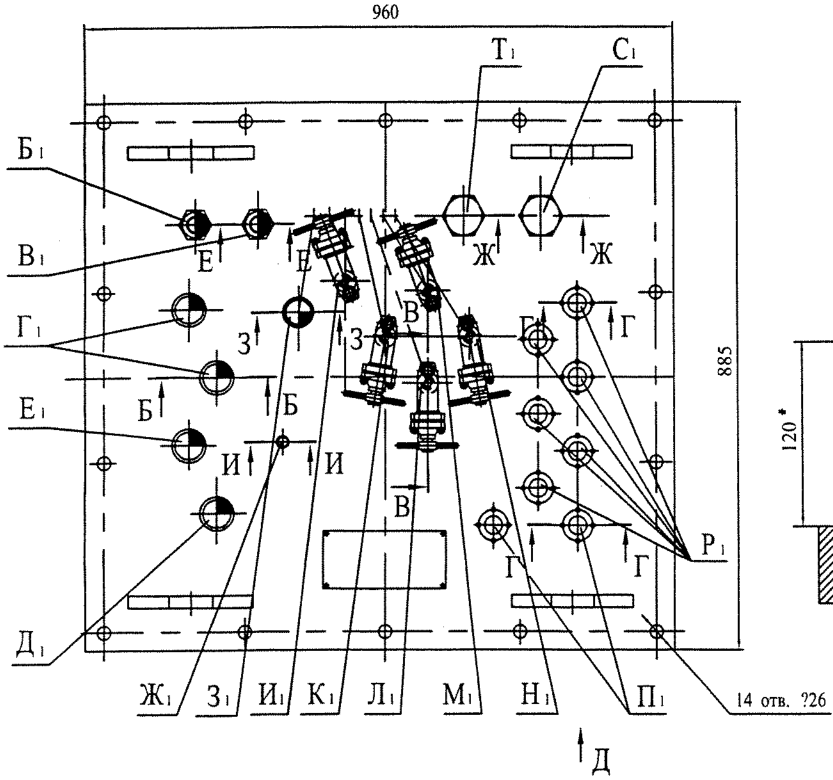


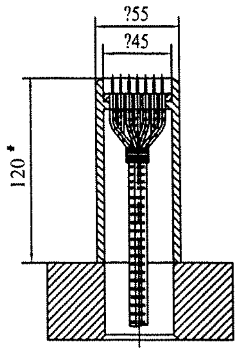
Fig.1.1 Target complex TC-1



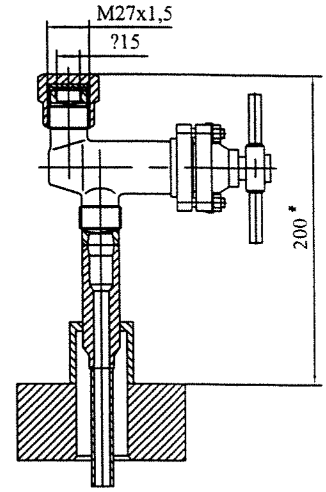
1–the target lid
2– cover
3– cover
4– rest
5– ear



Б-Б (1:2)



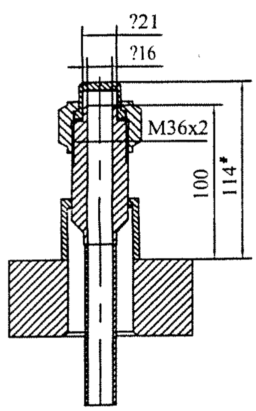
В-В (1:2)



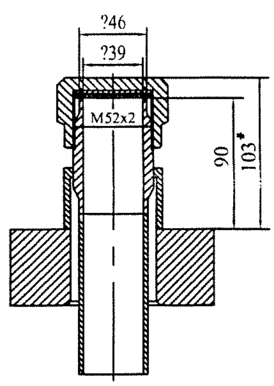
Pipe unions and penetration

Designation	Equipment	Notes
Б1	Pipe union for water supply to the shielding block cooling system	
В1	Water outlet pipe union of the shielding block cooling system	
Г1	Penetrations of thermoelectric transducers	
Д1	Penetration of flow meter cable	
Е1	Penetration of level indicator cables	
Ж1	Gas pipe union of container	
З1	Pipe union for initial filling with coolant	
И1	Gas pipe union of device for siphon break-down	
К1	Gas pipe union of drain tank	
Л1	Gas pipe union of pressure compensating tank	
М1	Pipe union for gas activity monitoring	Plugged & welded
Н1	Gas pipe union of demonstration	
П1	Penetration of pump cable	
Р1	Penetrations of cables for electric heaters	
С1	Pipe union for water supply to heat exchanger	
Т1	Water outlet pipe union of heat exchanger	

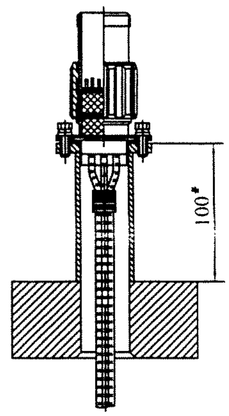
Е-Е (1:2)



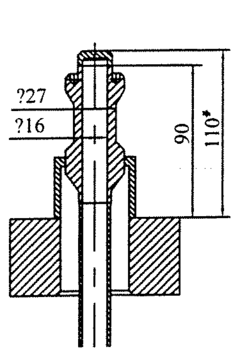
Ж-Ж (1:2)



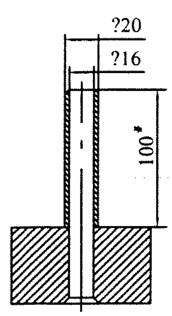
Г-Г (1:2)



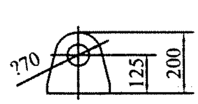
З-З (1:2)

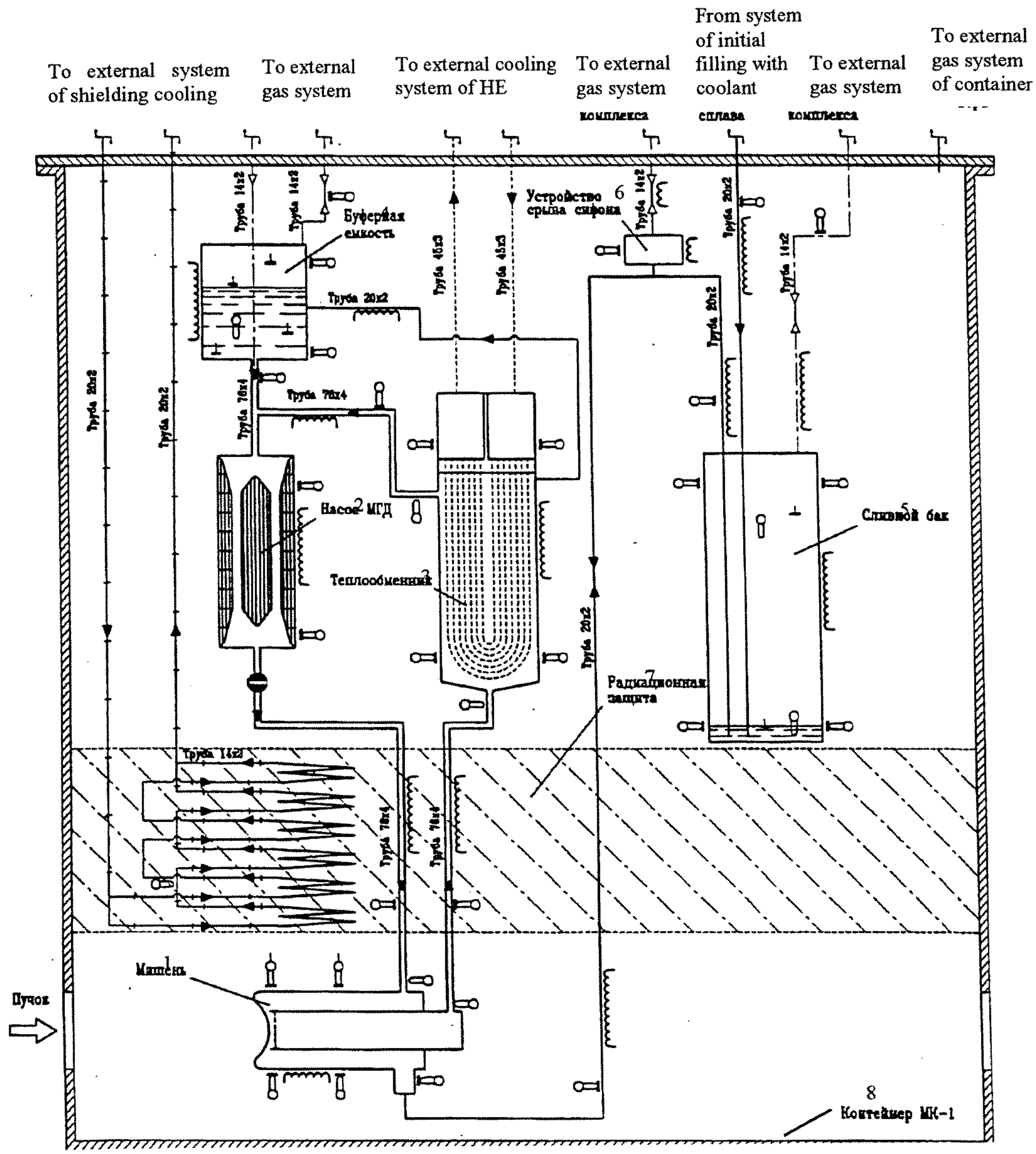


И-И (1:2)



Д (1:10)





Notification

1 – Target
2 – MHD-pump
3 – Heat exchanger
4 – Volume compensator
5 – Drainage tank
6 – Siphon interruption device
7 – Shielding block
8 – Container

Main pipe lines with coolant
Auxiliary pipelines with coolant
Pipelines of the HE cooling system
Pipelines of gas
Pipelines of shielding block cooling
Direction of liquid flow
Direction of gas flow
Seal

Electromagnetic flow meter
Immersable thermocouple
Surface thermocouple
Level signalizator
Electroheaters of components and pipelines
Bellows valve

Fig. 1.4 Basic hydraulic scheme of the TC-1

4. TC-1 conservation and packing

The disconnection of target circuit TC-1 from test facility system and its conservation have been made in accordance with guidance №559.10.Д8 including:

-the pipe for coolant transmission into the TC-1 was cut and welded;

-the inner gas cavities were filled with argon by pressure up to 0.5 mPa. The shut-off valves were closed and sealed with thread plugs with gaskets;

-the inner cavities of cooling pipelines were blown with argon and sealed with thread plugs with gaskets;

-response elements (plugs) were put at the electric connectors of supply cables and covered by protection tape.

-the input/output pins of thermal couples were reeled into hanks and fixed on upper plate of TC-1.

-TC-1 window was closed with transport protection cover.

4.1. Package design description

The target complex TC-1 is packed into the metallic container given in Fig.2.1. For transportation convenience before installation into the container TC-1 is fastened to the frame (Fig.2.2) using bracing elements 1, 2, 3. The frame with TC-1 is installed on the platform (Fig.2.1) and fastened by welding. The platform (Fig.2.3)is a frame fabricated from channels #15 and faced with a sheet of 3 mm thickness.

After installation on the platform the target complex is closed with the cover 3. The cover is a skeleton fabricated from the corners #5 and faced with a metallic sheet of 2 mm thickness. The cover is fastened to the platform using bracing elements 11, 12, 13.

For strapping convenience the package has a special trapezoidal structure (Fig.2.4) fabricated from channels #10. The trapezoidal structure has 4 ears for joining load-lifting means. It has also orifices where the platform inserts pass in. Fastening trapezoidal structure to the platform is given in Fig.2.1, block "Г", elements 6, 7, 8, 14.

The unit of fastening trapezoidal structure to the platform is presented in Fig.2.5, the insert – in Fig.2.6.

Elements and blocks of data acquisition and control system were packed in separate packages (wooden boxes). These elements and blocks were delivered by LANL to SSC RF IPPE for thermal and engineering tests of TC-1 on conditions of subsequent return.

To indicate stroke loads during transportation two accelerometers of NON-RESETABLE IMPACT INDICATOR type with response threshold of 5g were installed on TC-1 in perpendicular planes.(see Fig.1 of Addendum).

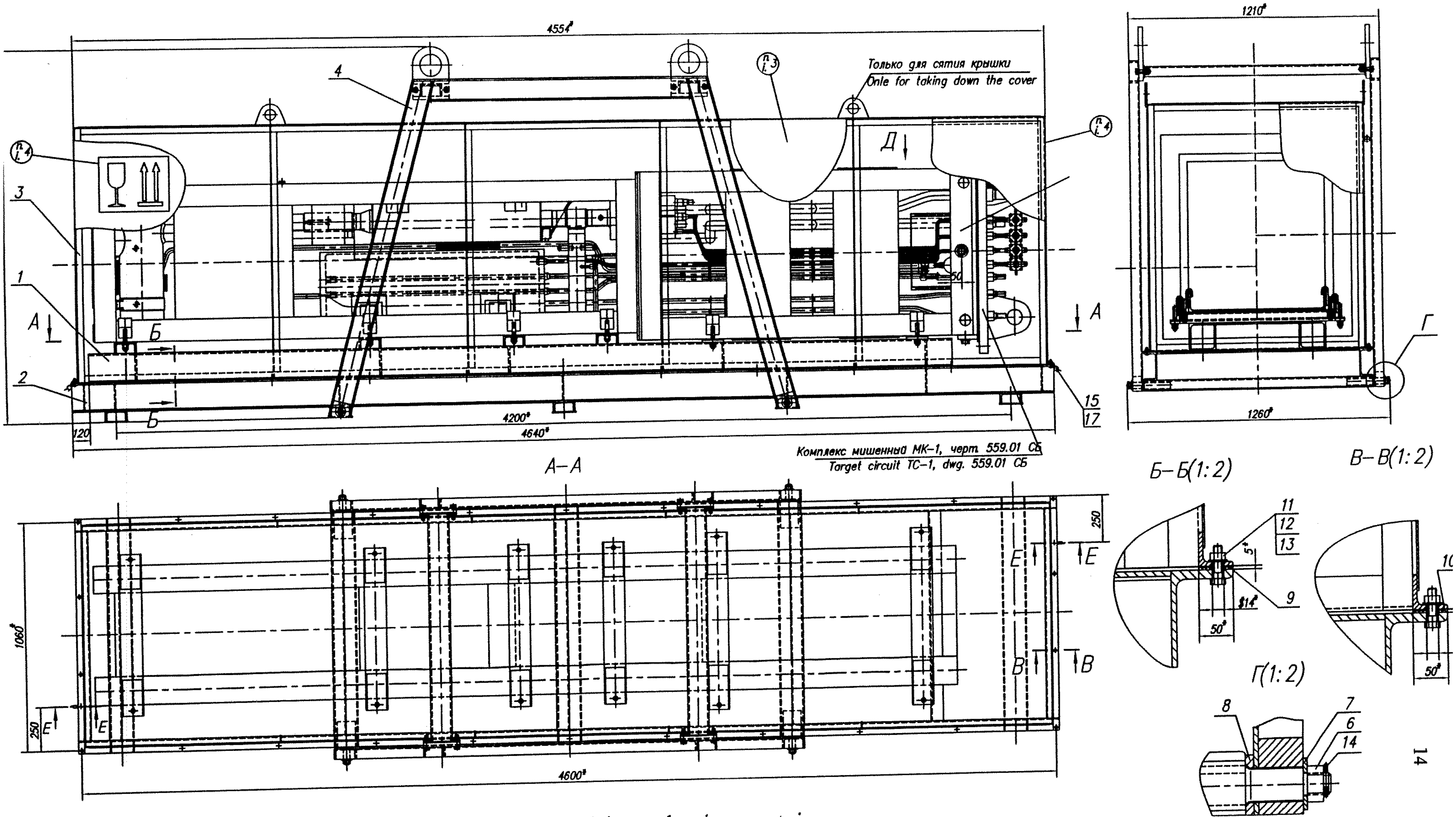


Fig. 2.1 The target complex TC-1 in packaging container.

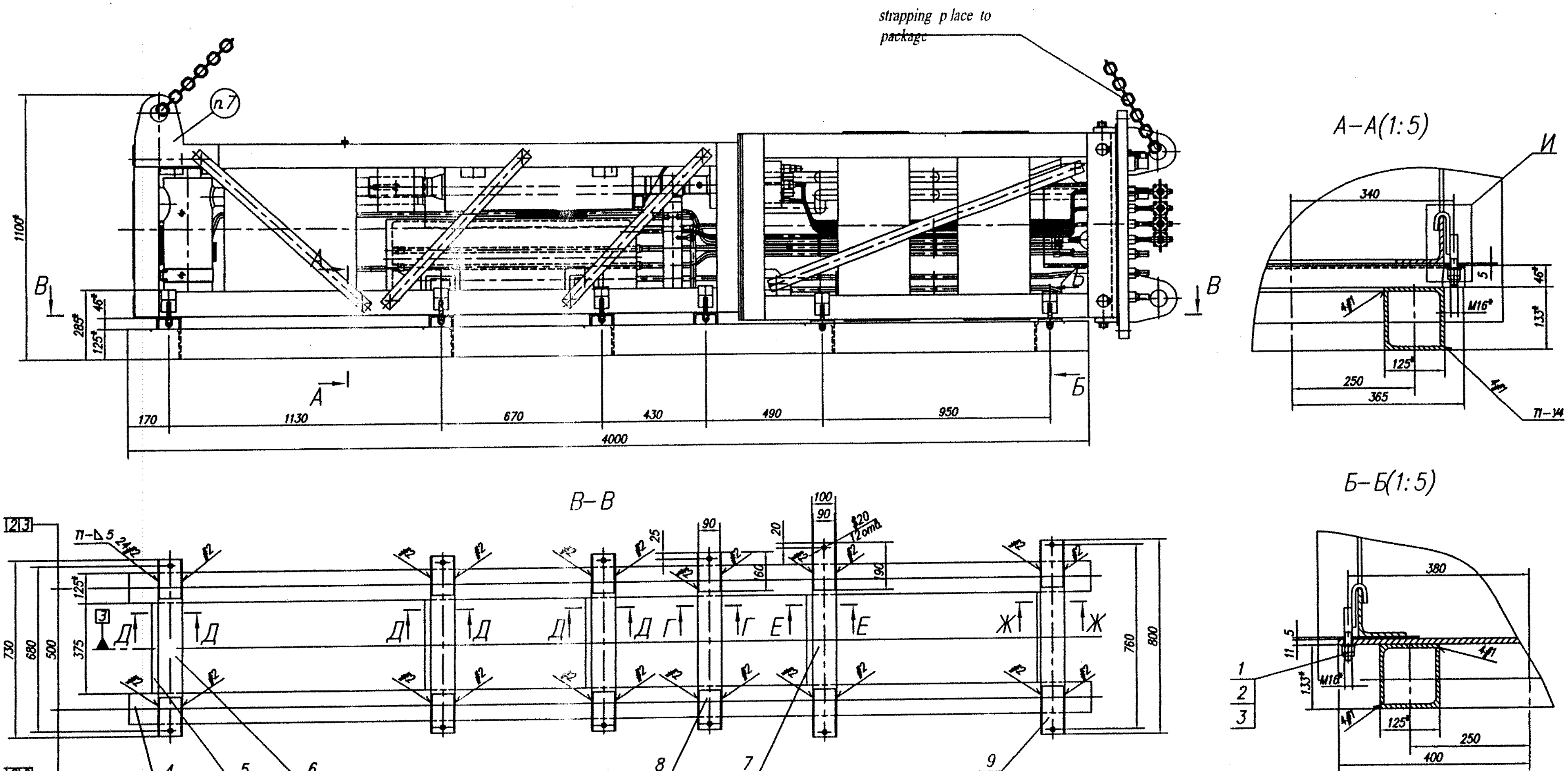


Fig. 2.2 Metallic truss for TC–1 package

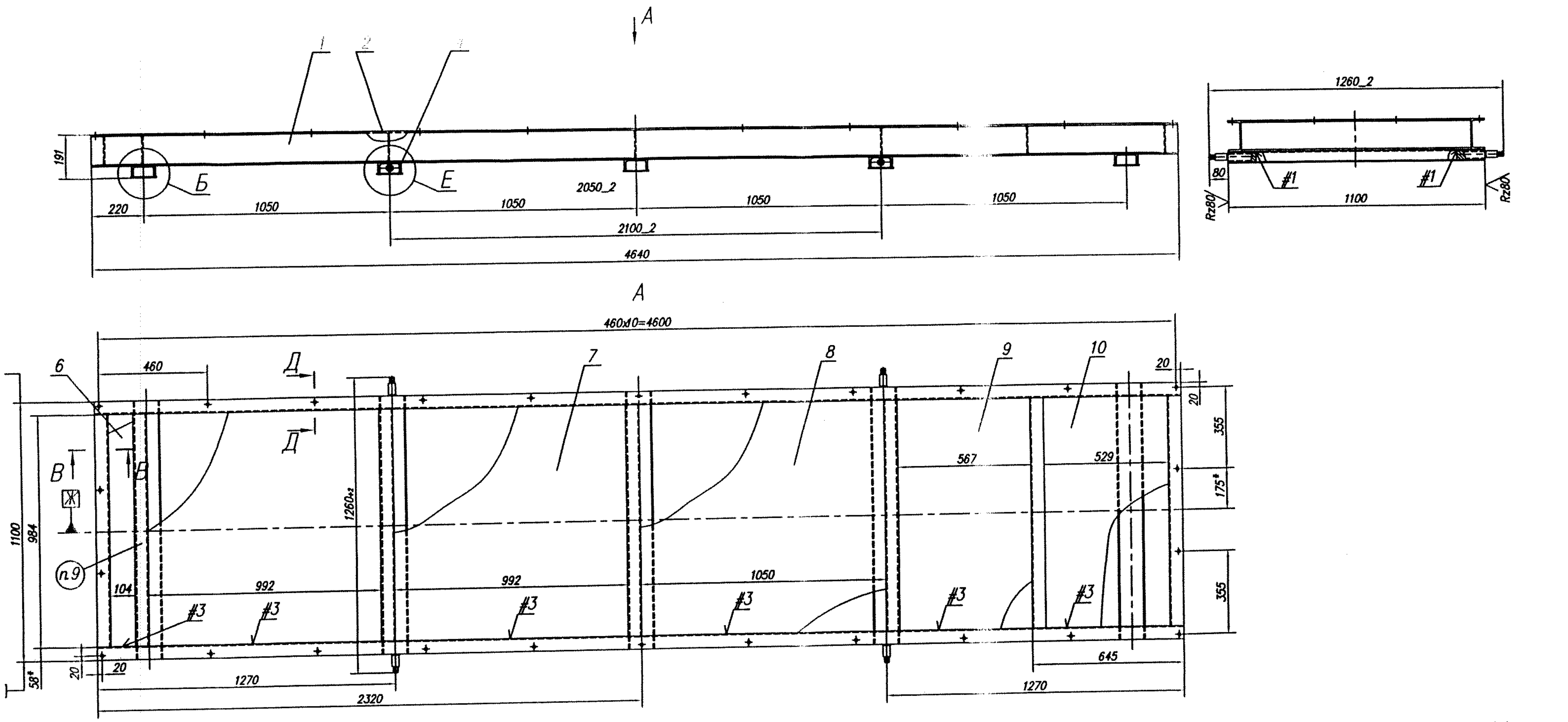


Fig. 2.3 Platform for TC–1 packing

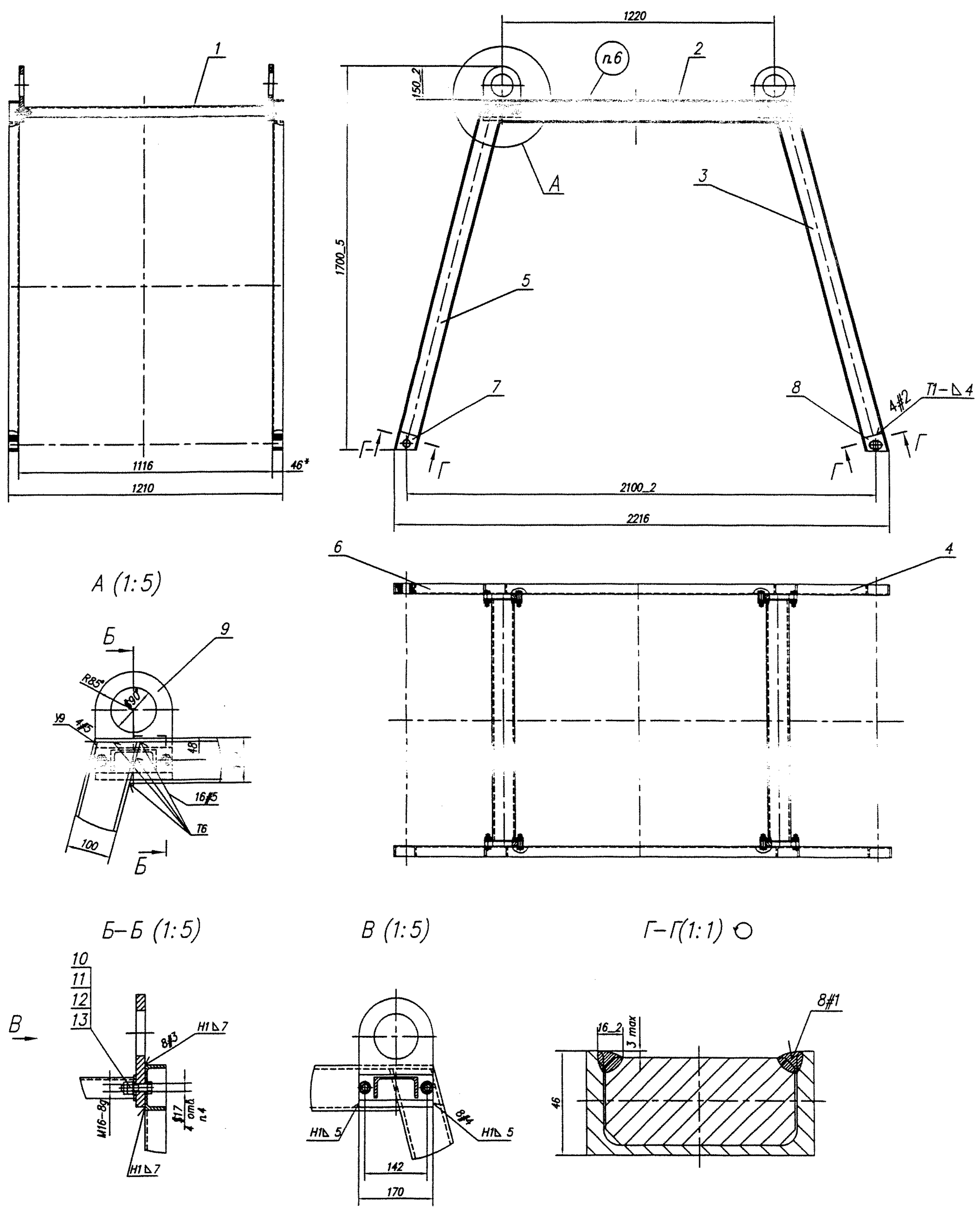


Fig. 2.4 Trapezoidal structure for TC–1 strapping

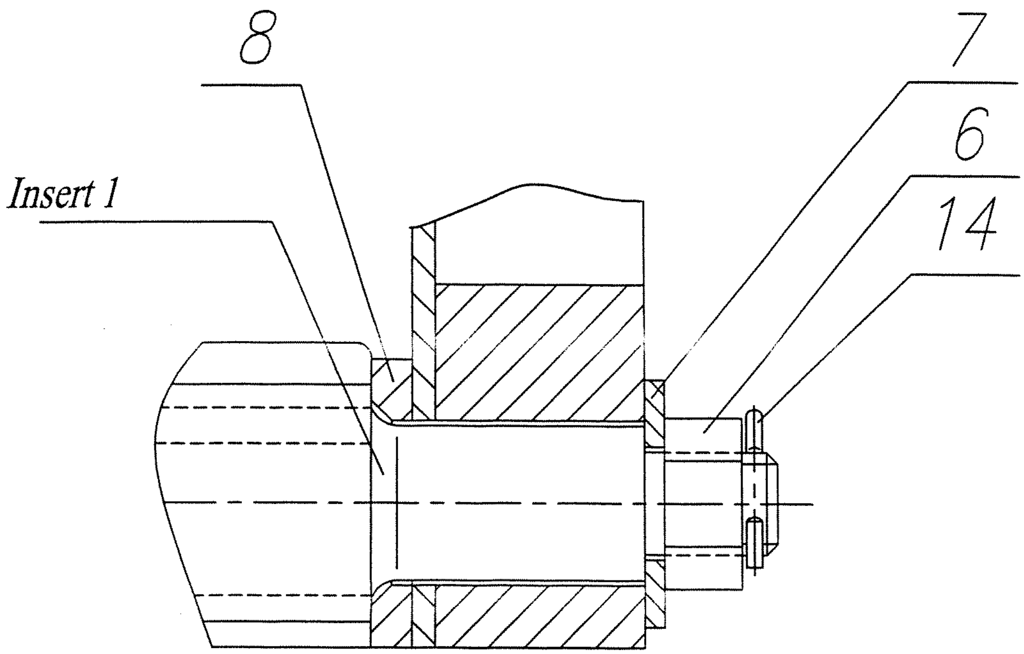


Fig. 2.5 Fastening trapezoidal structure to the platform

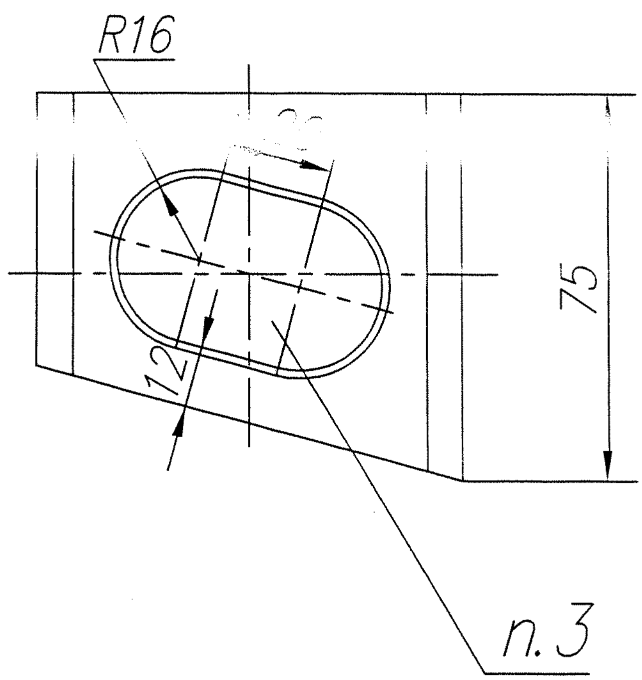


Fig. 2.6 Insert 2

4.2. Calculation of package strength

This calculation was made for the most loaded elements of the package.

4.2.1. Initial data

Package mass m=4640 kg.

Package loading is realized using a crane.

Overloading coefficient under package lifting with jerk k=2.

The inserts that are used for fastening trapezoidal structure to the platform are fabricated from steel 40. The ears for joining load-lifting means are made of steel Ст3сп. The ears are welded to the channels using electrode УОНИИ 13/55.

Ultimate stress limit σ_B and yield stress σ_T for structure material are:

for steel 40 (according to ГОСТ 1050-88)	$\sigma_в$=570 MPa, $\sigma_т$=335 MPa;
for steel Ст3сп (according to ГОСТ 14637-89)	$\sigma_в$=370 MPa, $\sigma_т$=245 MPa;
for welds (according to ПНАЭГ-7-010-89)	$\sigma_в$=431 MPa, $\sigma_т$=255 MPa;

Nominal permissible stresses taken as minimum value from $[\sigma]=\min\{\sigma_в/2{,}6;\ \sigma_т/1{,}5\}$ and they are

for steel 40	$[\sigma]$=219 MPa;
for steel Ст3сп	$[\sigma]$=142 MPa;
for welds	$[\sigma]$=165 MPa.

Average tangent stresses caused by mechanical loads do not have to exceed 0.5 $[\sigma]$.

4.2.2. Strength calculation

Calculation was made for the following most loaded elements under lifting TC-1 in the package with jerk:

- the inserts for following trapezoidal structure to the platform;
- ears;
- seams of welding the ears to the channels.

The weight of package:

P=mg=4640·9.81=45518 H,

where g=9.81 m/c^2 – gravitation acceleration.

Cut stress τ in the insert 1 (Fig.2.5) is:

$$\tau = \frac{k \cdot P}{4 \cdot A \cdot \sin\alpha} = \frac{2 \cdot 45518}{4 \cdot 707 \cdot \sin 75^\circ} = 33MPa < 0{,}5[\sigma] = 0{,}5 \cdot 219 = 109MPa,$$

where k=2 – overloading coefficient under the package lifting with jerk;

$$A = \frac{\pi d^2}{4} = \frac{3{,}14 \cdot 30^2}{4} = 707mm^2$$ - cross-section square;

α=75° – angle of the channel inclination;

d=30 mm – insert pin diameter.

Cut stress τ in the insert 2 (3, Fig.6) is:

$$\tau = \frac{k \cdot P}{8 \cdot A \cdot \sin\alpha} = \frac{2 \cdot 45518}{8 \cdot 408 \cdot \sin 75^\circ} = 25MPa < 0{,}5[\sigma] = 0{,}5 \cdot 219 = 109MPa,$$

where A=a·b=12·40=480 mm^2 – square;

a=12 mm – cross-section height;

b=40 mm – insert thickness.

Cut stress τ in the ear is:

$$\tau = \frac{k \cdot P}{8 \cdot A \cdot \sin\beta} = \frac{2 \cdot 45518}{8 \cdot 800 \cdot \sin 45^\circ} = 20MPa < 0{,}5[\sigma] = 0{,}5 \cdot 142 = 71MPa,$$

where $A=a\cdot b=20\cdot 40=800$ mm^2 – cross-section square;

$a=20$ mm – ear thickness;

$b=40$ mm – rated height of cross-section;

$\beta=45^\circ$ – rated inclination angle of the rope of load-lifting mean.

Cut stress τ in the seam of welding the ear to the channels:

$$\tau = \frac{k \cdot P}{4 \cdot A \cdot \sin\beta} = \frac{2 \cdot 45518}{4 \cdot 2296 \cdot \sin 45^\circ} = 14MPa < 0{,}5[\sigma] = 0{,}5 \cdot 165 = 82MPa,$$

where $A=2\cdot 0{,}7\cdot(h_1\cdot L_1+ h_2\cdot L_2)= 2\cdot 0{,}7\cdot(5\cdot 90+7\cdot 170)=2296$ mm^2 – rated square of the weld cut;

$h_1=5$ mm – leg of vertical weld;

$L_1=90$ mm – length of vertical weld;

$h_2 =7$ mm – leg of horizontal weld;

$L_2=170$ mm – length of horizontal weld.

Stress arising in the most loaded elements under lifting with jerk and transportation do not exceed permissible values.

Strength of the element for lifting and transportation TC-1 in metallic package is guaranteed.

5. Preparation and coordination of the documents on TC-1 transportation with regulation authorities of Russian Federation

Important work was carried out on preparation and coordination of the documents with regulation authorities of Russian Federation needed for TC-1 delivery to USA in accordance with p.2 of the Work Plan "Preparation and coordination of the documents on TC-1 exportation with RF regulation authorities"

As a result of this expertise accomplished in accordance with RF legislation on the procedure provided for Minatom enterprises Minatom Export Counsel decision was issued that export item (the target complex TC-1) does not fall under export control.

After obtaining Export Counsel decision necessary papers were prepared and permission for TC-1 exportation without license was obtained in Department of Export Control in Ministry of Economic Development.

Further the following works were carried out.

1. Choice of transport agent for TC-1 transportation to USA. In accordance with American party tender was announced among transportation companies. Choice was made by LANL represantivies in favor of Russian branch of American Company "GeoLogistics".

2. The scheme describing functional ties of TC-1 components was prepared.

3. Final version of package lists in Russian and in English was validated.

4. Final marking 4 boxes with TC-1 and with elements and block of data acquisition and control system with accordance of RF state standards and international rules of goods transportation.

5. Drawing up a statement of TC-1 readiness for consignment to USA.

6. Co-ordination with ISTC and transport agent "GeoLogistics" joint efforts, itinerary, time-table of TC-1 movement from Obninsk.

7. Preparation of the final version of conditions and features of TC-1 delivery to USA. Shipment was realized under EXW conditions as described in the INCOTERMS-90.

8. Loading TC-1 and its delivery to Moscow on Butovo custom together with "GeoLogistics" representative.

9. Custom validation together with ISTC representatives.

10. Consignment to Saint -Petersburg for further transportation to USA.

6. Inspection of TC-1 conditions after transportation

In the course of transportation in principle some damage of TC-1 is possible and inspection (incoming control) of TC-1 conditions was planned after delivery to USA. The guide for incoming control was developed. It is presented as Addendum to this report.

Incoming control purpose is to check serviceability of TC-1 after transportation.

The incoming control includes the following stages:
- external visual inspection;
- checking accelerometers indicating shock loads applied at the target complex TC-1 during its transportation;
- checking condition of preservation of the inner surfaces;
- inspection of electric heaters, control systems and measurement of MHD pump insulation resistance.

Incoming control was carried out in UNLV early in August 2002 according to p.A-C with participation SSC RF IPPE representatives. Checking according to p.D should be made later before TC-1 connection with the external systems.

Visual inspection showed that there was not any visual traces of TC-1 damage.

Both accelerometer snapped, this was evidence that during transportation stroke loads had place with acceleration more than 5g.

Excessive argon pressure in the inner cavity of TC-1 was measured as ~0.1 MPa (13 psi).This is evidence that TC-1 loop is seal ed, there was no air penetration, and the inner surfaces are in regular conditions without oxidation.

7. Conceptual design of TC-1 external systems for the conditions of University of Nevada

Development of a number of external systems that are needed for the target complex TC-1 commissioning in University of Nevada (UNLV) has been carried out on conceptual level.

These systems comprises:
1. Heat exchanger cooling system.
2. Coolant technology system.
3. Gas-vacuum system.

This development includes basic schemes with description of component characteristics and parameters. External systems construction will be made, apparently, using components and equipment produced in USA. Detail engineering design of these systems can be performed together with USA specialists.

7.1. Heat exchanger cooling system

The system is designed for heat removal released in the circulation loop through the heat exchanger (HX).

Heat exchanging surface of HX in the target complex TC-1 was designed for removal power ~600 kW from the circulation loop (the primary loop). Under operation in isothermal mode in UNLV MHD-pump is a heat source in the primary loop. The power realized in the primary loop from the pump and transferred to the cooling system is ~6 kW.

7.1.1. Cooling system description
Flow diagram of the cooling system is presented in Fig. 7.1.

The cooling system components:
- the pump with capacity up to 0.5 kg/s;
- the tank for hot water reserve (THWR), volume 15 l;
- electric pile (EP), power 25 kW;
- cooler (C), power up to 25 kW;
- heat exchanger (HX) of TC-1, water volume 12 l;
- expansion tank (ET), volume 50 l, gas volume 20 l, water volume between the indicators of upper and lower levels 15 l;
- valves, 11 samples, pipelines of inner diameter 20 mm.

The cooling system comprises small and large circulation loops. The small circulation loop includes the pump, the electric pile, the tank for hot water reserve, the cooler, connecting pipelines with connector between head and suction lines. The small circulation loop is designated for its filling with cold water, heating up to 200°C and filling the heat exchanger of TC-1 with hot water. The large circulation loop includes the small loop, without the connector with valve V8 and TC-1 heat exchanger with pipelines and it is designated for heat removal from the primary loop.

The meter of water level should be located in to the expansion tank with two set point for upper and lower levels. Gas volume of the tank (20 l) and water volume between the set point (15 l) were chosen in order to meet the following conditions in the course of filling TC-1 heat exchanger:

- parameters values in the start of filling: water is on the upper level, pressure is 3.5 MPa, water temperature is 200°C;
- parameters values in the end of filling: water is on the lower level, pressure is more than 2.0 MPa, water temperature is 200°C.

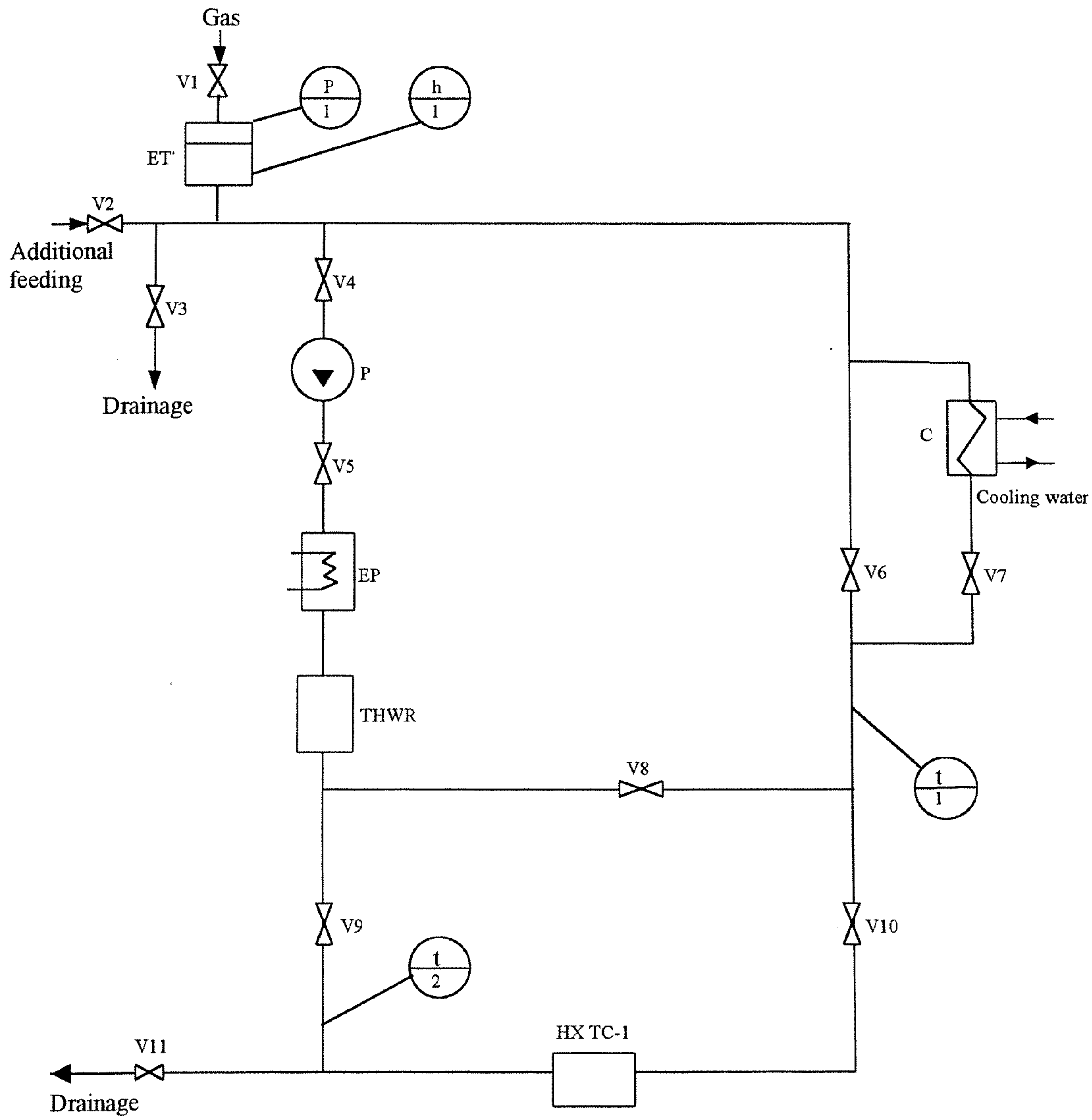


Fig. 7.1 Flow diagram of the cooling system

P	- pressure meter
h	- level meter with set points of the upper and lower levels
t	- temperature meter
ET	- expansion tank
EP	- electric pill
THWR	- tank of hot water reserve
HX	- heat exchanger
C	- cooler
P	- pump
V1÷V11	- valves

7.1.2. Start-up the cooling system

Start up the cooling system can be realized in two modes of TC-1 operation:

- TC-1 was heated and it is maintained in hot conditions. The coolant is circulated in the primary loop using MHD-pump;
- TC-1 is maintained in cold conditions. The large circulation loop is filled with cold water.

TC-1 heating is realized simultaneously with water in the cooling system. Procedure of heating TC-1 and the cooling system is described in the document "The target complex TC-1. Operation guide 559.01 PЭ".

The cooling system start-up when TC-1 has been heated and it is maintained in hot conditions begin from filling TC-1 with water with parameters:

- pressure 3.5 MPa, temperature 200°C.

Pressure and water temperature in the cooling system can be decreased but in all cases when the coolant is in the circulation loop HX feeding with water with temperature lower the 160°C has to be excluded to avoid the coolant solidification in intertubular space of the heat exchanger.

7.2. Coolant technology system

Specific feature of lead-bismuth coolant is the fact that under interaction with oxygen slags (phases containing oxides of the coolant itself, components of structural steels and others)can be formed. The slags can deposit on the loop surfaces, decrease transport cross-sections of channels (up to its blocking), aggravate thermal and hydraulic performance of the loop.

Therefore for successful operation of the loop it is necessary:

- to restrict contacts of the coolant and the loop with media containing oxygen, in particular, with air;
- to clean the coolant and the loop of excessive oxygen (in the event of this contact appearance).

These tasks are solved under coolant technology realization. "Coolant technology" means a complex of management and engineering measures as well as processes and systems (devices) for their realization. These measures are applied for providing given (required) conditions of the coolant and the loop surfaces under construction, commissioning, operation and repair works on TC-1.

Coolant technology system is a set of devices for coolant technology realization. The devices are placed both in the circulation loop and outside the container.

In dependence of destination, the loop design, mode of operation etc. composition of the technology system may be different and devices used may be realized on the basis of different physical and chemical processes. In TC-1 coolant technology processes based on effects of hydrogen mixtures with water vapor on the coolant and the loop are basically recommended.

Under interaction hydrogen water vapor mixtures witch the coolant, its admixtures and the materials of the loop surfaces the reactions of the following type have place.

$$Me_xO_y + YH_2 \leftrightarrow XMe + YH_2O \quad (1)$$

with equilibrium constant

$$K_{(1)} = \left(\frac{P_{H_2O}}{P_{H_2}} \right)^y$$

$$|O| + H_2 \leftrightarrow H_2O \quad (2)$$

$$K_{(2)} = \frac{P_{H_2O}}{P_{H_2} \cdot a_{|O|}}$$

where :
Me и Me_xO_y – metallic and oxides phases, relatively;
$|O|$ – oxygen dissolved in the coolant;
P_{H_2}, P_{H_2O} – partial pressure of hydrogen and water vapor in the gaseous phase;
$a_{|O|}$ – thermodynamic activity of oxygen in the coolant.

Using reactions (1) and (2) one can carry out a number of technology processes under maintenance of different P_{H_2O} / P_{H_2} values in gaseous mixture being in contact with the coolant and the loop surfaces. These processes are:

- hydrogen cleaning (redacting) the coolant oxides;
- passivation (oxidation) of the materials of the loop surfaces;
- changing (decreasing or increasing) thermodynamic activity of oxygen in the coolant.

Besides performance of diagnostic modes of operation is possible. These modes result in qualitative and some cases quantitative determination of the coolant contamination with oxides and metallic admixtures as well as identification of the loop surfaces conditions

The rates of reactions (1) and (2) run under technology processes and diagnostic modes realization can be estimated by measuring hydrogen change in gaseous phase.

The version of basic scheme for the coolant and the loop treatment using mixtures with hydrogen and water steam is presented in Fig.7.2.

The system includes the apparatus for preparation and supply of gaseous mixtures into the loop (I) and the apparatus for discharge of gaseous mixtures from the loop (II).

The apparatus (I) includes the following devices:
1 – injection of gaseous mixtures;
2 – cylinders with gaseous mixtures (Ar) + H_2 (C_{H_2} = 0,1 vol.% и C_{Ar} = 30 vol.%);
3 – gaseous reducers;
4 – line for gas sampling and discharge into ventilation;
5 – values for precise control;
6 – vacuum manometer;
7 – gas flow meter;
8 – pipeline for system evacuation;
9 – protective capacity;
10 – water steam generator;
11 – level meter;
12 – line for distiller supply;
13 – baffles;
14 – grid;
15 – cut-off valves;
16 – electric heater with power control;
23 – temperature meters;
24 – gas filter;

Capacity (9) prevents water penetration from water steam generator into gaseous pipelines before it.

The apparatus (II) includes the following devices:
17 – condenser with pipeline (18) for gas supply from TC-1 gaseous communications;
19 – line for gas sampling;
20 – vacuum manometer;
21 – valve for precise control;
22 – electric heater;
23 – temperature meter;
26 – gas filter;
27 – gas analysis device.

System operates as the following.
Gaseous mixture from gas cylinders (2) with given flow rate G_1 measured with gas flow meter (7) is supplied to water vapor generator where it is moisten to required value P_{H_2O} / P_{H_2}
Ratio P_{H_2O} / P_{H_2} in mixtures after vapor generator is determined by equation

$$\frac{P_{H_2O}}{P_{H_2}} = \frac{P_{H_2O}}{(P - P_{H_2O}) \cdot C_{H_2}}$$

where P_{H_2O} – pressure of saturated vapor at water temperature in vapor generator, P – pressure in the system measured with vacuum manometer (6), C_{H_2} – volume part of hydrogen in gaseous mixture in cylinder (2).

Flow rate G_2 of gaseous mixture after vapor generator is determined by equation:

$$G_2 = G_1 / (1 - P_{H_2O}/P)$$

After vapor generator gaseous mixture can be fed to any gaseous cavities of TC-1 loop or directly to the coolant flow. In the last case the injector of gaseous mixtures (1) is used, which is located on the pump suck. In the course of the coolant circulation gaseous mixture is transported through the loop interacts with the coolant and the loop surfaces, it is partly separated and comes to gaseous cavity of extension tank.

Drop of gaseous mixtures from any TC-1 cavities is realized using the apparatus (II) for mixtures discharge.

<u>Destination and characteristics of the main devices of the coolant technology system</u>

1. Injector of gaseous mixtures is a hollow cylinder with orifices in the shell. The tube for gas supply from gas system is lead up to the upper bottom of the injector. The device provides supply of gaseous mixtures $Ar\text{-}H_2\text{-}H_2O$ to the coolant with flow rate from 5 to 50 normal liter per hour in the form of small bubbles.

2. Protective capacity (9) prevents water penetration into gas pipelines.

3. Water vapor generator (10) includes bubbling device with level meter, pipeline for distiller feeding, buffaloes for preventing water drops transferring into outlet branch pipe, perforated grid with 10 orifices of 2 mm diameter. Water volume in 10 orifices of 2 mm diameter. Water volume in the generator is 1.5 l. Temperature of the generator and gaseous pipelines behind it is regulated in the interval 20-150°C.

4. Gas flow rate meter (7) is standard rotameter with measure interval 0-50l/hour. It is possible to use other standard devices with the same measure limits.

5. Condenser provides moisture condensation up to dew point 20°C in gaseous mixture removed from the loop with flow rate up to 50 normal liters per hour. Periodic drop of condensate is envisage from lower part of the condenser.

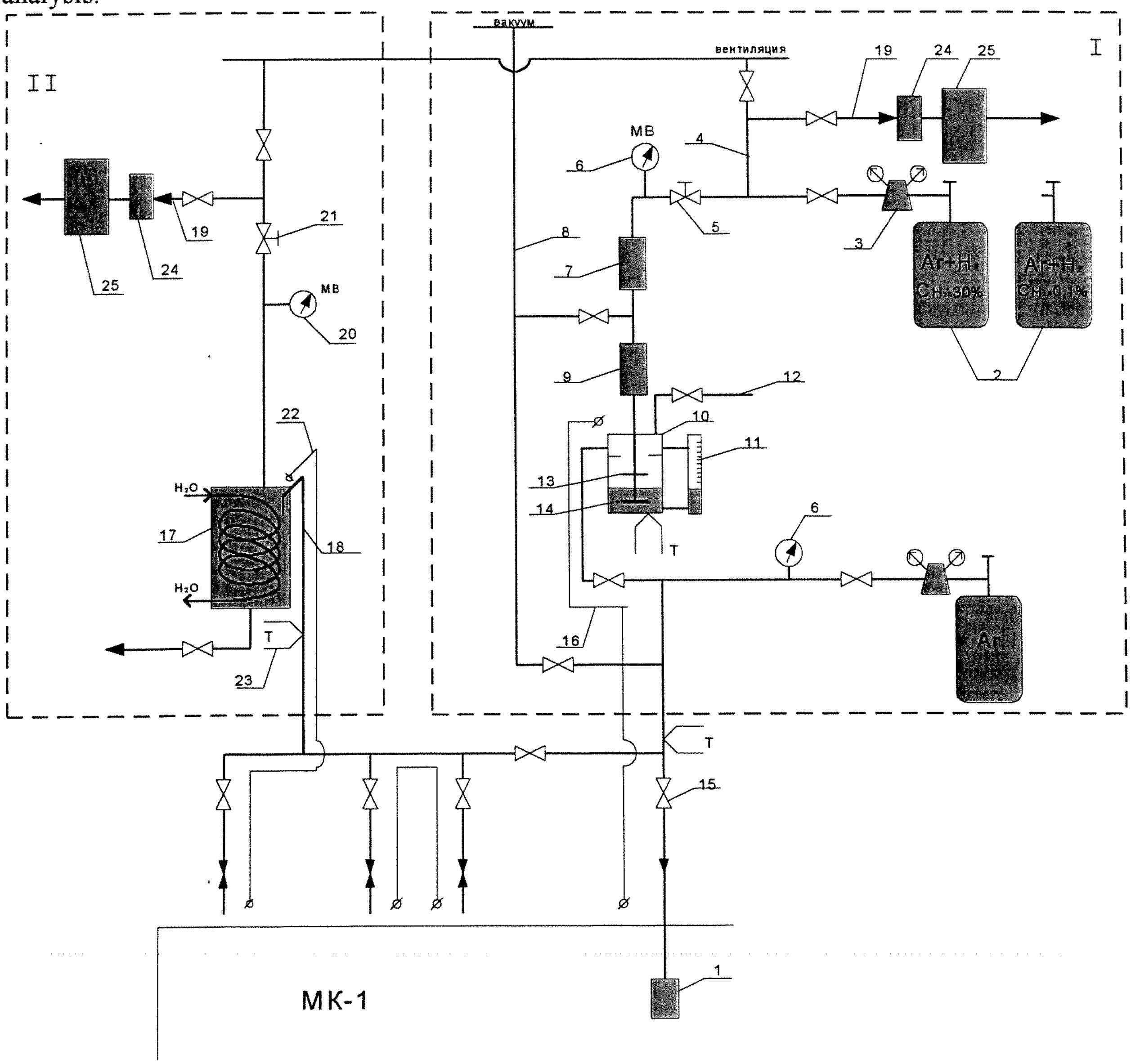
6. Pipelines (18) for gas removal are heated up to 150°C before the condenser.

7. Valves for precise control (5, 21) are standard control valves for gases with flow rate limits controlled 5-50 normal liters per hour.

8. Vacuum manometers (6, 20) are devices of standard design with measurement limits 0÷0.25 MPa.

9. Cut-off valves for gas (15) and the coolant (27) are valves of standard design.

10. Devices (25) for gas analyses provides control of hydrogen, nitrogen, oxygen and other components in gaseous mixtures supplied to TC-1 and removed from TC-1 as well. It possible to use any standard device (chromatograph, for example). In dependence of the device type it is possible to use one (common for apparatus I and II) or two and more devices for gas analysis.



7.3. Gas-vacuum system

Gas vacuum system is designated for realization necessary pressure of inert gas and vacuum in TC-1 and the facility cavities as well as for preparation of gaseous mixtures and providing its injection into TC-1 loop using components of the coolant technology system.

Gas-vacuum system comprises:
- two mechanical roughing pumps;
- transporting gas cylinders with argon and hydrogen with reducers;
- gas-vacuum manifolds;
- valve for precise control;
- throttling device;
- protective valve;
- pipelines and fitting.

Connection of gas-vacuum system pipelines with TC-1 gas cavities is realized using thread coupling. Since the coolant overshoot into TC-1 cold (not heated) zones is possible under operations of the circulation loop filling from the drainage tank and vice versa maximum value of gas pressure and the rate of this pressure increase must be restricted. Regulated gas supply during the coolant pressurizing is realized through the valve for precise control and the throttling device that comprises ten disks of 1mm diameter. In order to exclude possible pressure increase on the throttle inlet under the coolant pressurizing gas is fed from the receiver (gas capacity detachable from pressure source). The protective valve is installed on the pipeline for gas feed to TC-1 with the pressure 0.6 MPa (excessive) as a set point. The receiver with the volume 120 l consist of three transporting cylinder connected in parallel and used also for gas mixtures preparation.

The system fitting consists of standard bellow valves of C26184 type with internal diameter 10 mm. Control of gas pressure and vacuum is realized using vacuum manometer (accuracy class 2.5, scale interval 0.02 MPa) placed on the receiver manifold and gas-vacuum manifolds.

The scheme of the gas-vacuum system and the part of the coolant technology system scheme (apparatus II) are presented on Fig. 7.3. A part of the components is common for the gas-vacuum and the coolant technology systems (gas cylinders, vacuum manometer, valves for precise control of gas flow rate, vacuum pumps, flow rate meters and others).

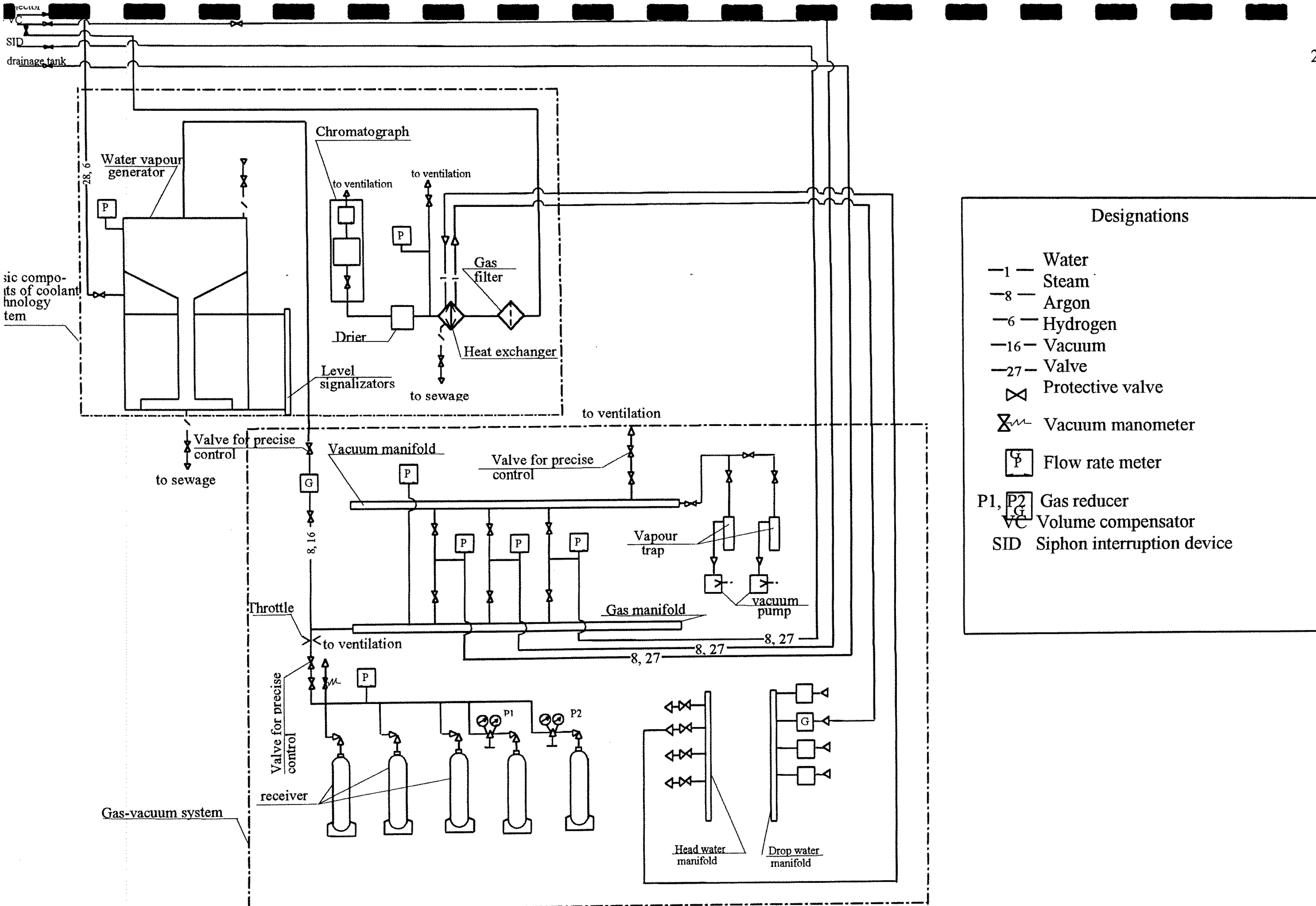


Fig. 7.3 Basic scheme of the gas-vacuum and the coolant technology systems

8. The program of TC-1 start-up and testing in UNLV

This program has been presented in the Work Plan of second phase of the Project (the tasks 7-15, seen part 2).

The tasks 7, 8 are development, fabrication of the external system and TC-1 connection with these systems. Before this connection serviceability conductivity of electric heating system and thermocouple transducers, electric insulation resistance of MHD-pump, electric heaters and transducer as well (p.D of the guide, see Addendum).
Some modernization of data acquisition and control system will be required (p.7.4) in comparison with the system that had been realized on thermal and engineering tests of TC-1 in SSC RF IPPE, in particular, because of appearance of the heat exchanger cooling system that the control is needed for.

Development of exploitation guides is necessary for UNLV condition, one guide for TC-1 tests without heat exchanger cooling system on other for resource testing (the task 13).

At present the procedures of the coolant technology during TC-1 start up and testing in UNLV are not planned taking into account the fact that the circulation loop of TC-1 is in inert atmosphere and sealed (there is no argon leaks).

The proposals on TC-1 reconstructions and the program of further investigation shall be developed with consideration of the experience gained in TC-1 isothermal tests. It is assumed that later some laboratory on investigation of thermal hydraulic, corrosion in lead-bismuth coolant will be realized in UNLV on TC-1 basis.

Conclusion

As the main results obtained in the first phase of the Project #2083 one can note the following.

1. Package for the target complex TC-1 transportation to USA was designed and fabricated.

2. TC-1 was disconnected from test facility, conservated and packed. Relevant package was fabricated and elements and blocs of data acquisition and control system were packed. These blocks and elements have been delivered by LANL earlier for thermal and engineering tests of TC-1 in SSC RF IPPE on the conditions of their return.

3. The documents on TC-1 exportation to USA were prepared and coordinated with regulation authorities of Russian Federation. Decision of Minatom Export Consel that export item (TC-1) does not fall under export control and Permission of Department of Export Control in Ministry of Economic Development for TC-1 exportation without license were obtained.

4. Together with ISTC custom validation of export items was made and transport agent choosed. (Russian branch of "GeoLogistics" Company) TC-1 was delivered in June 2002 to University of Nevada State (UNLV).

5. The guide was developed for inspection (incoming control) of TC-1 conditions after its transportation to USA. Early in August incoming control was carried out in UNLV after TC-1 delivery. The control confirmed TC-1 serviceability.

6. Conceptual design was carried out for the external systems needed for TC-1 start in heat exchanger cooling, gas-vacuum system and the coolant technology system.

7. The program of TC-1 start-up and isothermal testing in UNLV was developed. This program is the basis of the Work Plan of the second phase of the Project #2083. Period of the Project validity was prolonged for 2 years with UNLV funding as a Partner.

ADDENDUM

APPROVED BY:

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TARGET COMPLEX TC-1

Incoming control

559.01 D13

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2002

Contents

1. General propositions

1.1. The objective of incoming control is to ascertain proper condition of TC-1 target complex and possibility of its use for its main purpose.

1.2. The incoming control includes the following phases:
- external visual inspection;
- checking accelerometers indicating shock loads applied at the target complex TC-1 during its transportation;
- checking condition of preservation of the inner surfaces;
- inspection of electric heaters, control systems and measurement of MHD pump insulation resistance.
-

1.3. Checking condition of preservation of TC-1 inner surfaces, inspection of electric heaters, control systems and measurement of MHD pump insulation resistance are carried out with TC-1 in vertical position.

2 External visual inspection

2.1. To make visual inspection of package (Fig. 1) in order to check:
- package integrity;
- absence of mechanical damage, deformation or pollution;
- presence of seals.

2.2. To remove cross-piece 1 and cover 2 from the package base 3 (see Fig. 1) after dismantling 4-7 and 9-12 items.
Target complex placed in horizontal position on the package base is accessible for inspection and checking (see Fig. 2).

2.3. To check (see Fig. 2):
- state of indicators 2. Indicator balls should be held by the springs; any displacement of the balls means that TC-1 target complex has been subject to over 5 **g** shock loads;
- state of protection coating on the outer surface of TC-1 metal structures;
- absence of mechanical and other damage of TC-1 metal structures;
- integrity of all penetrations in the cover of TC-1 target complex (see Fig.1.3);
- presence of plugs in the piping penetrations and valves of TC-1 cover. Valves B1-B5 (559.01 Г3) should be closed and sealed. The ends of pipelines downstream V1 and V3 valves (pipe connections M1 and H1 in Fig. 1.3) should be plugged and welded;
- presence of tags and marking on the connectors and ends of cables;
- condition of surface of fit collar on TC-1 cover;
- presence of four stops 4 of TC-1 cover;
- presence of transportation laths 5 on TC-1 metal structures;
- state of target membrane. External visual inspection of the target is carried out with TC-1 complex placed in vertical position and removed target cover 1 (Fig. 1.3).

2.4. If any damage is revealed, statement is drawn indicating extent of damage and its cause.

3. Checking of preservation of the inner surface

3.1. To disconnect TC-1 target complex from the package base 1 (Fig. 2) by dismantling clamps 3.

3.2. To put TC-1 target complex into vertical position (see Fig. 1.3) using ears 6 (Fig..2) and ears 5 (Fig. 1.3).

3.3. To remove from TC-1 target complex transportation laths 5, ears 6 (Fig. 2) and caps 2 and 3 (Fig. 1.3) covering wells for the upper shielding blocks. All transportation elements are marked with red. Dismantling of shielding cover 1 and four stops of TC-1 cover can only be carried out if the target complex is used for its main purpose with the proton beam.

3.4. To determine whether argon gas excess pressure is maintained in the inner cavity of coolant and gas circuits. For this purpose, the following procedures should be performed:

3.4.1. To remove plug from the pipe union of one out of three valves: B2, B4 or B5 (559.01Г3). Layout of valves and penetrations is presented in Fig. 1.3.

3.4.2. To connect external gas/vacuum system to the pipe union of one out of three valves (B2, B4 or B5) by the pipeline or hose. By opening connected valve, to check presence of excess argon gas pressure in the inner cavity of coolant and gas circuits.

If there is no excess argon pressure in the inner cavity, some amount of gas should be added from the external gas/vacuum system through receiver, where ~0.1 MPa (1.0 kg/cm^2) argon pressure is maintained. This procedure is carried out until 49 kPa (0.5 kg/cm^2) excess pressure value is reached, pressure/vacuum gauge of the external system being used for control. Upon reaching required pressure value, the valves should be closed.

3.4.3. To disconnect external gas/vacuum system from the target complex, put the plug with rubber gasket on the valve pipe union and seal it.

During storage of TC-1 target complex, excess argon gas pressure should be maintained inside coolant and gas circuits, and its monitoring should be performed every month. Recommended excess pressure value is ~ 49 kPa (0.5 kg/cm^2). In the process of gas replenishment, gas pressure should not be lower than 10 kPa (0.1 kg/cm^2).

3.5. To determine, whether excess pressure of argon gas is maintained in the inner cavity of heat removal circuits of heat exchanger and shielding block. For this purpose, the following procedures should be performed:

3.5.1. Plugs should be removed from cooling circuit pipelines.

3.5.2. Argon cylinder should be connected in turn to the pipelines of heat removal circuit inlets through pressure regulator and argon blow-down should be carried out during ~1 min with ~98 kPa (1.0 kg/cm^2) gas pressure at the regulator outlet.

3.5.3. Gas cylinder should be disconnected, and plugs with rubber gaskets should be installed on the heat removal pipelines and sealed. Time interval between the end of blow-down and plug installation should not exceed 5 min.

3.6. Results of inspection of preservation of the inner surface should be presented in the statement.

4. Inspection of electric heaters, control systems and measurement of MHD pump insulation resistance

4.1. All penetrations, leads and joints are arranged on the cover of TC-1 target complex. The layout and designations of penetrations and pipe unions on TC-1 cover are presented in Fig. 1.3.

4.2. To make measurement of heater insulation resistance relative to the housing (see 559.01 РЭ).

Measurement should be made by mego hmmeter for 250 V voltage between leads of XR1-XR6 joints, to which heaters are connected, and housing. Electric connections diagram is presented in Fig. 3. Insulation resistance should be equal to at least 1.0 kΩ.

4.3. To check direct current resistance of heaters at 20±5°C temperature. Resistance values of the main and stand-by heater zones should be as follows:

3.2±0.16 Ω - for ## 1-3 heater zones;

5.3±0.26 Ω - for ## 4-8 heater zones.

4.4. To make measurements of resistance of insulation of thermoelectric transducers. Measurements should be made by 100V megohmmeter. Insulation resistance should be equal to at least 20 MΩ.

To make measurements of resistance of thermoelectric transducers. The measurements should be made by the bridge having error within ±1.5%. Electric resistance should be equal to at least 120 Ω.

All measurements should be performed at 20±5°C.

4.5. To make measurements of resistance of insulation of spark-plug level indicators. These measurements should be made by 100V megohmmeter. Insulation resistance should be equal to at least 100 MΩ.

Measurements should be performed at 20±5°C.

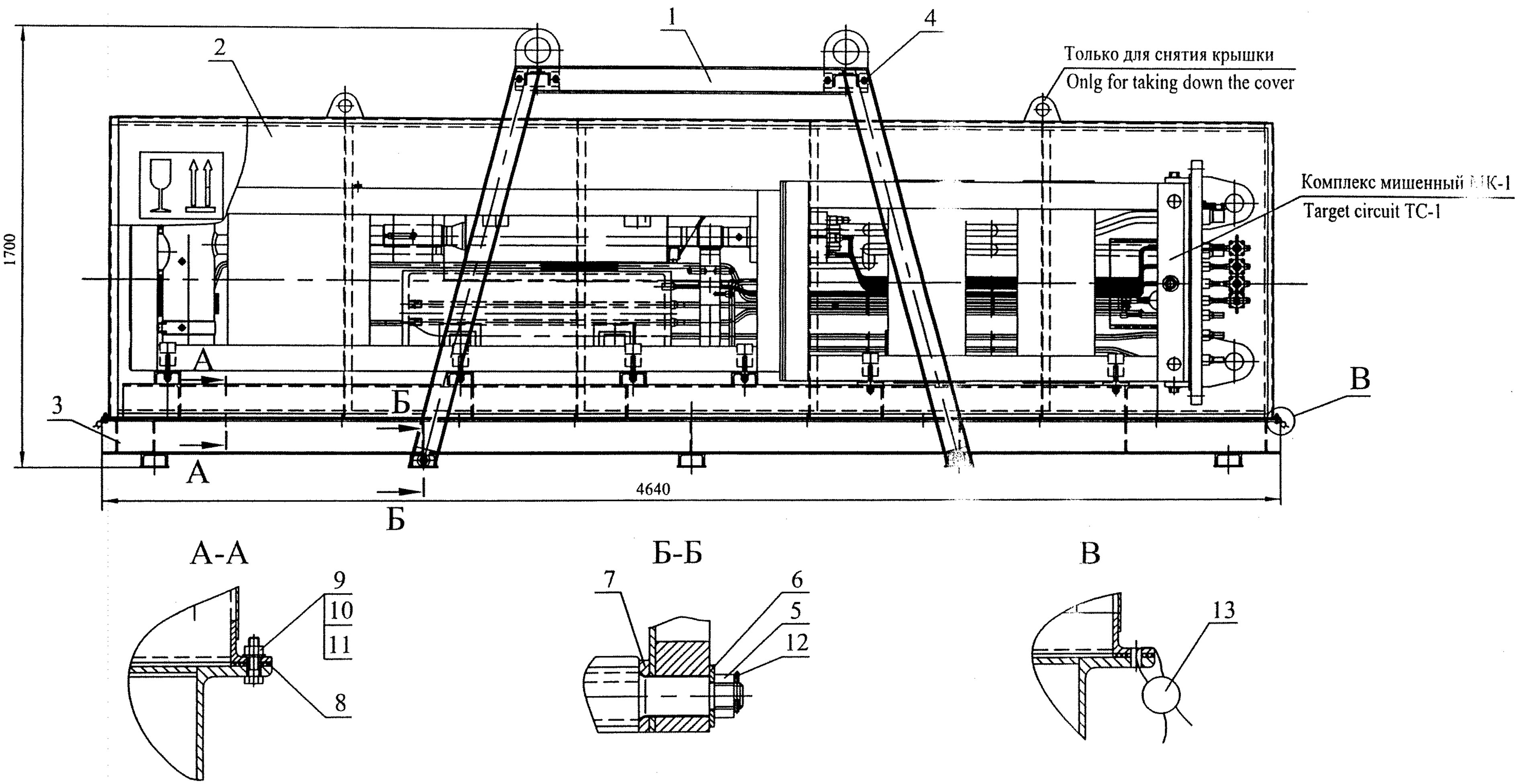
4.6. To make measurements of resistance of insulation of electromagnetic flow meter. The measurements should be made by the bridge having error within ±1.5%. Electric resistance should not exceed 100 Ω.

4.7. To make measurements of resistance of insulation of MHD pump power supply cables (Fig.3).

Measurements should be made by megohmmeter for 500V voltage between leads of XR7-XR8 joints and housing. Insulation resistance should be equal to at least 0.5 MΩ.

To check D.C. resistance of winding phases at 20±5°C temperature. Resistance should be equal to about 0.27Ω value for all phases.

4.8. Results of inspection of electric heaters, control elements and insulation resistance should be presented in the statement.



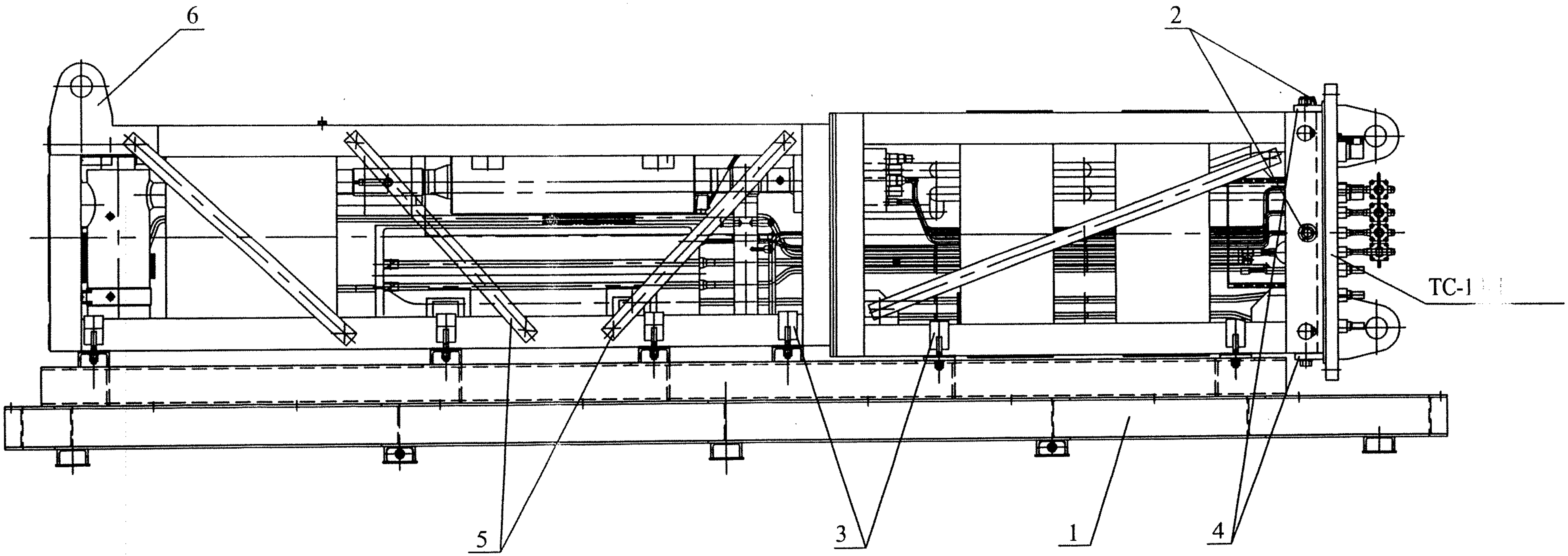
1 - Cross-bar
2 - Lid
3 - Package basis
4 - Bolt

5 - Nut
6 - Washer
7 - Washer
8 - Gasket

9 - Bolt
10 - Nut
11 - Washer
12 - Split pin

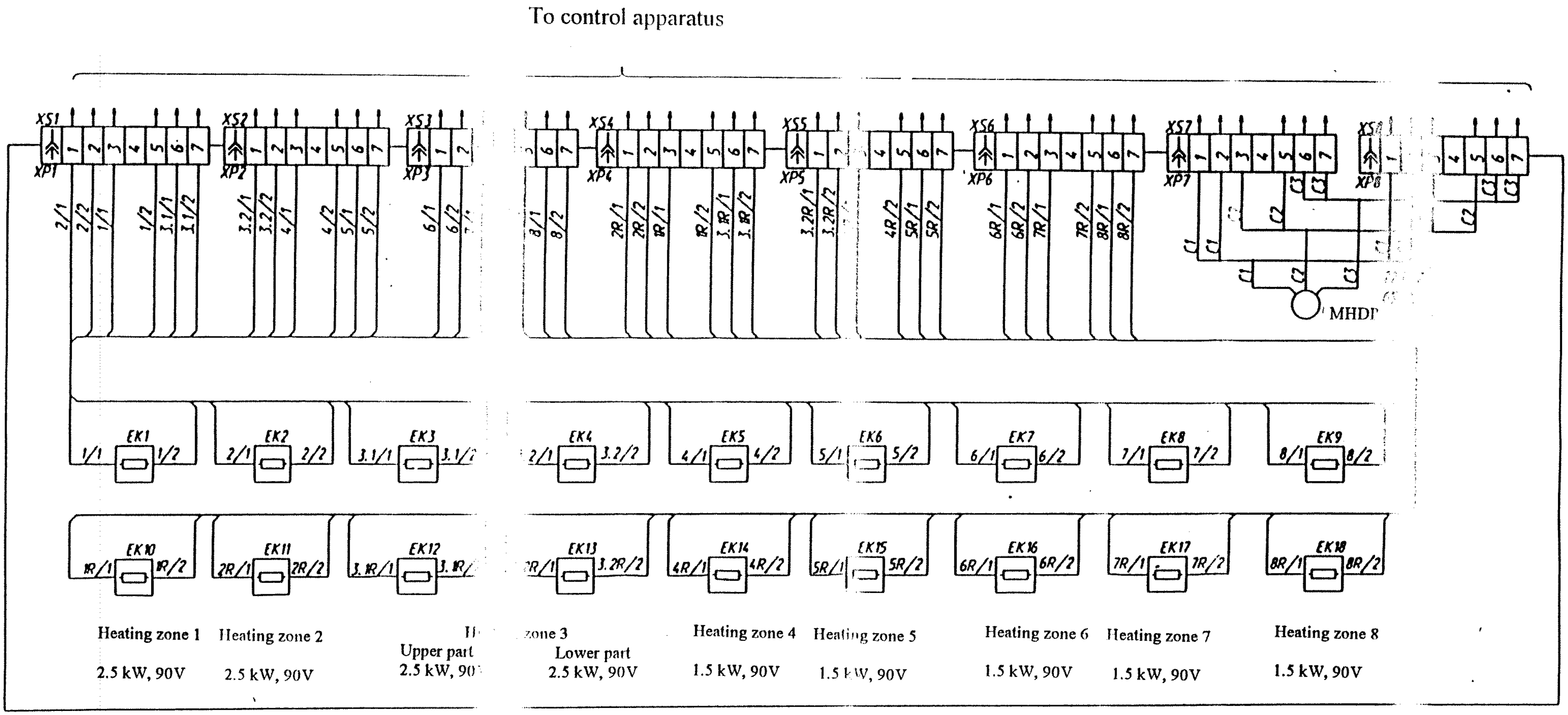
13 - Seal

Fig.1. The target complex package



1 - Package basis
2 - Indacator
3 - Hold-down
4 - Rest
5 - Transport slat
6 - Ear

Fig.2. The target complex TC-1 in horizontal position



ig. 3. Scheme of electric connections